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End Use of Solvents Containing Volatile Organic Compounds

Research Corp of New England, Wethersfield, CT

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16. ABSTRACT

Recently published information on production and end uses of individual solvents was reviewed. The information was supplemented through interviews with solvent producers and marketers. Information on solvent content of consumer products was obtained by a rapid testing procedure. A solvent survey provided information about major solvent uses. Criteria were developed for the exemption of small sources from emission regulations. Economics, process technology, energy, emission contribution of small sources, and enforcement aspects were considered. Information is provided on methodology for development of an emission inventory of solvent sources. Point sources are to be identified by a questionnaire survey. A factor is given (13 lb per capita) to be used in assessing the contribution of area sources.

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by

Ned Ostojic

The Research Corporation of New England
125 Silas Deane Highway
Wethersfield, Connecticut 06109

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EPA Project Officer: Joseph A. McSorley

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DEFINITIONS

Solvent consumption is the quantity of organic compounds used nationwide annually as solvents and is expressed in gg/y or 10^6lbs/y. When used as solvents, the compounds are not chemically modified in the course of their application. They almost always evaporate during or after their application. Solvent consumption consists of identified and unidentified consumption, as defined below.

Identified solvent consumption represents that portion of solvent consumption which takes place in specific identified end uses.

Unidentified solvent consumption represents that portion of solvent consumption which, due to insufficient information, cannot be attributed to any specific end uses. Estimates of the unidentified solvent consumption and the methods used to arrive at these estimates are presented in Section 6, Part I.

Solvent production is the annual quantity of organic compounds produced domestically and/or imported, minus exports, which are at least partially used as solvents. Solvent production equals the sum of solvent and non-solvent end uses.

Solvent end uses are those manufacturing and non-manufacturing activities which lead to solvent evaporation. In solvent end uses, compounds do not undergo chemical modifications. They almost always evaporate during or after their application. Thus, solvents are distinguished from e.g., chemical raw materials which may be used in a reaction in which they are chemically irreversibly changed.

Non-solvent end uses are those applications in which the organic compounds undergo chemical modification, such as in chemical synthesis or combustion.

Solvent is an organic compound which is at least partially consumed in solvent end uses as defined here. Even though some compounds are predominantly applied in non-solvent end uses they are still referred to as solvents as long as they are consumed in any solvent end uses.

Units for measurement of solvent production and consumption are gg/y (gigagrams per year) or lbs/y. One gigagram is equal to one thousand metric tons or to one million kilograms, or to 2.2 million pounds.

END USES OF SOLVENTS CONTAINING VOLATILE ORGANIC COMPOUNDS

PART I

END USES OF ORGANIC SOLVENTS

FINAL REPORT
BY
NED OSTOJIC

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EPA PROJECT OFFICER
MR. JOSEPH A. McSORLEY
INDUSTRIAL ENVIRONMENTAL RESEARCH LABORATORY/RTP

EPA TASK MANAGER
MR. EDWIN J. VINCENT
OFFICE OF AIR QUALITY PLANNING AND STANDARDS

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1.0 SUMMARY AND CONCLUSIONS

Background, Problem Definition

Emissions of volatile organic compounds (VOC) are one of the major targets of the control programs being developed by the EPA Office of Air Quality Planning and Standards. Organic solvents are a major part of these emissions. In the current EPA estimates, the sources of much of these emissions are not known. Knowledge of the end uses of these solvents provides an important clue as to the ways in which solvents are emitted to the atmosphere. The objective of this project was to determine total domestic solvent consumption and to provide as complete an end use breakdown of this consumption as possible.

Methodology

Recently published information on production and end uses of individual solvents was reviewed in the initial phase of the project. When this published information was found to be incomplete, it was supplemented through interviews with solvent producers and marketers. A rapid laboratory method for determination of the approximate solvent content in consumer products was developed to complement the findings of the solvent survey. The method was applied to products from sixteen product categories.

The solvent survey provided information about major uses for major solvents. The information on those end uses, in which solvents are used in minor quantities was frequently not available. This unidentified solvent consumption was determined by subtracting the total identified consumption from the total quantity of solvent produced. Adjustments were made for the non-solvent uses in which the compounds are chemically modified (e.g. chemical raw materials, fuels, etc.). The methods used for determination of unidentified solvent consumption are presented in Section 6.2.

Findings Summary

End Uses

The findings are summarized and compared with current EPA estimates in Table 1.

TABLE 1

SUMMARY OF SOLVENT END USE CLASSIFICATION

	Consumption gg/y		
	TRC (this study)	Current EPA Estimates (ref.1)	Difference[(b)]
TOTAL IDENTIFIED SOLVENT USES	6,900**	5,500**	25%
Industrial Uses (Point Sources)	5,530	4,540	22%
Consumer/Commercial Uses (Area Sources)	1,100	320	240%
Other Uses (Special Sources)[(c)]	230	660	-65%
TOTAL UNIDENTIFIED SOLVENT USES	900	2,900	-69%
TOTAL SOLVENT USES[(a)]	7,800**	8,400**	-7%

gg = 10^3 mt = 10^6kg = 2.2 10^6 lbs.

**rounded off to 2 significant figures.

(a) Non-solvent uses in which compounds are chemically modified (e.g. chemical raw materials, fuels) are not included. For discussion on non-solvent uses please refer to Section 6.0.

(b) (TRC - EPA)/EPA.

(c) Special sources consist of cutback asphalt and pesticdes.

To facilitate application of the findings in VOC control programs and especially in the VOC emission inventories, the solvent end uses were classified in industrial and consumer/commercial sectors. The industrial sector corresponds to point sources which are covered by solvent emission questionnaires, used by the air pollution control agencies for emission inventory purposes. Conversely, the consumer/commercial sector corresponds to area sources which actually represent an assembly of smaller sources dispersed in a given region. These sources can not be effectively inventoried by means of emission questionnaires, and are therefore, treated collectively (e.g. on a "per capita" basis).

Total annual domestic solvent consumption, which excludes non-solvent uses such as raw materials for chemical synthesis, fuels, etc., was estimated at 7800 gg/y (17,000 x 10^6 lbs/y).

Unidentified Solvent Consumption

Significant progress was realized in reduction of unidentified solvent consumption. The presently unidentified consumption of 910 gg/y represents a 69% reduction with respect to the unknown consumption in the current EPA estimates. Industrial processes account for most of the previously unidentified solvent consumption. Adhesives, aerosol products, and household products are some of the other solvent end uses underestimated or overlooked in previous studies.

Solvents

One single group of solvents, special naphthas, account for 55% of the total solvent consumption, with the next most used solvent, methanol, accounting for 5%. Special naphthas is a common name for all petroleum distillates used as solvents. Published information on these solvents is very incomplete and an extensive interviewing program involving producers and marketers was required. Due to their exceptional importance, special naphthas are discussed separately in Section 9.

Consumer Products

A rapid method for determination of the approximate solvent content in various products was developed and applied on samples from 16 product categories. The results, presented in Table 11, Section 10, provide additional perspective on solvent consumption patterns by complementing and verifying the findings based on the survey of solvent production and end uses.

Completeness of Study

Perhaps the best way to estimate the completeness of this study is to compare the results with those obtained by application of a different methodology. This study, which is based on survey of individual solvents, could for instance be compared to a survey of solvent usage by individual industries. The agreement between the results would indicate that the estimates were accurate. This is because it is unlikely that the same error would be committed using two sufficiently different and independent approaches. EPA has conducted independent surveys of some major solvent end uses. Good agreement of their findings[1] with our results, as shown in Section 8.0, indicates good degree of completeness of this survey.

2.0 RECOMMENDATIONS

1. It is recommended that the study of solvent content in consumer products be expanded to correct for some of its present deficiencies related to its limited scope. For instance, regional and seasonal variations in the types, brands and quantities of the products displayed on supermarket shelves, should be taken into account. The number of surveyed and analyzed products should be increased to achieve a statistically valid representation of the individual product categories.

2. The laboratory method for determination of solvent content of various products should be further refined and more extensively tested. Its potential for wider applicability, e.g., as an enforcement tool, should be explored.

3. Prediodic updating of production and end use consumption for major solvents and solvent groups is recommended. Since the major solvent group, special naphthas, which represents 55% of the total domestic solvents comsumption, is also a subject of close attention by the Department of Energy and other agencies of the government, it is suggested that the ways of conducting a periodic revision of end uses of these solvents be explored as a combined effort of the involved agencies and departments. The computerized solvent data system developed by TRC for this study could be used in this effort.

4. Further refinement and verification of the solvent usage data base created in this study could be achieved by incorporating the growing fund of knowledge of solvent emissions gained directly from the extensive ongoing and recently

conducted source evaluation program. It is therefore recommended that the already accumulated information be reviewed and incorporated into the solvent usage data base. Communication channels should be opened and means developed to continuously include new source testing results into this base.

3.0 INTRODUCTION

Organic solvents constitute one of the major contributors to volatile organic compounds emisssions. In the course of application of a solution, the solvent will eventually evaporate and thus possibly contribute to the volatile organic emissions. Knowledge of the ways in which organic solvents are used is needed by the Office of Air Quality Planning and Standards of the EPA in their effort to develop control programs for these emissions.

According to current EPA estimates, total domestic annual solvent consumption amounts to 8,400 gg/y (19,000 x 10^6 lbs/y). Sixty five percent of this amount was consumed in various identified industries, processes, products and other end uses. The remaining thirty five percent was also used as solvent, but no specific information about the ways in which it was used was available.

The objective of this work was to identify end uses for as large a part of the total solvent consumption as possible, using the most recent information available. The problem was approached in three ways:

- By survey of secondary information;
- Through gathering of primary information;
- By determination of solvent content in consumer products using an analytical method especially developed for this purpose.

At the outset of the study, it was realized that thorough advantage should be taken of the already accumulated and organized statistical information on solvent production and end uses. Such information is referred to here as secondary. It is compiled by government agencies and private market research and analysis firms.

It was soon realized that for the major group of solvents, special naphthas, which accounted for more than 50% of total solvent consumption, the available secondary information was inadequate. Thus, an effort was made to obtain as strong an insight as possible into the production and end uses of special naphthas by means of contacts with the producers and marketers of these solvents. Such effort is referred to here as gathering of primary information.

The methodology developed and applied in this work is described in Section 4. Secondary and primary information gathering and techniques employed in the consumer product survey are discussed individually.

Section 5 contains the results presented both in a summary and an expanded tabular form. Classification of end uses into industrial, commericial and consumer sectors is presented. Factors found to affect the reliability of the results are discussed.

Contribution of the individual solvents to the total unidentified consumption and reasons why the unidentified consumption could not be further reduced for the leading solvents is reviewed in Section 6. Discrepancies among the data from various studies are used to demonstrate the uncertainties in the production and end use estimates in Section 8.

Special attention is devoted to the presentation of the findings of the primary information gathering regarding production and end uses of special naphthas in Section 9. The basis used to arrive at the final estimates is discussed.

The results of the consumer product survey are presented in Section 10. The factors limiting the universality of these findings are discussed.

4.0 METHODOLOGY

4.1 Secondary Information

The assessment of end uses of most solvents was achieved by using secondary information sources. Secondary information is compliled by the government and specialized research agencies directly from production, marketing and purchasing personnel in industry. The information may be collected with regular periodicity, or it may be a one time specialized study. Some of the information is published and easily available. Many specialized studies, however, are not publicly available and some of the results of these studies may be obtained from the researchers at their discretion.

The two sources of secondary information found to be the most helpful were the Chemical Marketing Reporter[2] and the Chemical Economics Handbook.[3]

Secondary information on production and end use of organic chemicals is most often organized by individual compounds or groups of compounds. The search was conducted for those compounds which are either known to be used as solvents, or were likely to be used as solvents because of their properties.

In quite general terms, organic solvents are relatively stable compounds, which are normally separated from solution by evaporation and thus must have reasonably high volatility. Major factors determining the suitability of a solvent for a given application or end use are its capability to form a required solution, lack of reactivity, volatility, environmental impact of its emission and cost. Very often a mixture of solvents, representing a compromise of the above factors is used instead of a single solvent.

Information received from various sources often differed in the degree of completeness. It ranged from only the yearly production to a complete breakdown of all end uses. Information from more than one source was often available for a given solvent. In such cases certain uses may have been identified by only one of these sources. The information from all the sources was then combined into the final end use assessment. In doing this, priority was given to the most recent information which was then supplemented as needed from the older sources with finer end use breakdown.

Most compounds used as solvents may have many other uses as well. Such other uses include chemical processing, fuel etc. Some information sources would explicitly state the total solvent use for a given compound. In such cases, solvent consumption in various unidentified end uses was calculated as the difference between the total solvent use and the sum of the identified solvent uses. However, occasionally, total solvent use would not be stated explicitly. It was then estimated from the available information.

The unidentified end uses for a given compound would most often be expressed as a fraction of total consumption, entitled "other uses." The unidentified solvent uses constitute a fraction of these "other uses." Whenever the source indicated that most of the "other uses" category could be attributed to solvent use, the entire amount of "other use" consumption was reported as "unidentified solvent uses." When no information was available the fraction of solvent use in the "other use" category was assumed to be equal to the fraction of solvent use in all the identified end uses.

4.2 Primary Information

When the search of secondary information failed to further reduce the unidentified end use consumption, primary information sources were contacted. Primary information sources are people engaged in production and marketing of solvents and of the products containing solvents. Major factors found to affect the reliability of the estimates and the difficulty of information gathering were:

- product distribution pattern - Direct sales to end users by a few major producers facilitate extrapolation of partial information; also, more complete and detailed information on end uses is likely to be available. However, if the solvent is marketed by many small distributors, the process of gathering primary information may become forbiddingly complex.

- solvent's share of the manufacturer's total production - If the solvent represents only a minor fraction of the manufacturer's total business, it is likely that less attention will be devoted to its marketing and the associated end use studies.

- familiarity with end uses - The person supplying the information may not be sufficiently familar with some end use to correctly distinguish between solvent and "nonsolvent" use.

- precision of product definition - A solvent mixture may be marketed by various manufacturers or distributors under different names. The chemical composition or the key physical properties of the mixture, which may allow its classification, may not be known to the person supplying the information.

- the proprietary character of information - Producers and distributors are reluctant to supply information which they deem proprietary.

Many other factors were found to contribute to the success or failure of the primary information gathering. These included the general courtesy of the person supplying the information, how readily the requested information was available to the person supplying it, etc.

4.3 Methodology for Determination of Solvent Content of Consumer Products

With an increasing number of identified solvent end uses in this study, it became evident that many of them could not be clearly classified into industrial, commericial or consumer categories. Since it was felt that knowledge of solvent consumption in these sectors might be helpful for regional allocation of the volatile organic emissions, a survey of the solvent content in consumer products was conducted.

In order to arrive at the solvent content of consumer products it was necessary to determine:

- the average solvent content of the individual consumer product categories, and
- the annual consumption of those consumer products which contain solvents.

4.3.1 Determination of Solvent Content of Individual Consumer Product Categories

The development of a rapid method of determination of the solvent content of consumer products was initiated after numerous attempts to arrive at the solvent content information directly from the manufacturers of consumer products failed. The major reason stated by the manufacturers of the indivdual products for refusal to reveal the solvent content of their products was the proprietary nature of such information.

From an analytical standpoint consumer products fall in three general categories: waxes, liquids, and aerosols. The method employed for analysis of waxes consisted of simple forced evaporation of the product in the laboratory hood over a heated plate. The temperature of the inner surface of the watch glass containing the product was about 40°C. The method is similar to the ASTM method for determination of solvents in paints.[4] However, the determination of water in the products as specified in the method was not conducted in this study. Thus, the results may show too high a solvent current for some of these products.

Solvent content of liquids was determined by the direct injection of liquid into a modified gas chromatograph. The gas chromatographic column was replaced by a manifold, illustrated in Figure 1. The major purpose of the manifold was to allow the introduction of samples with large solvent content directly into the instrument without exceeding the linear range of the flame ionization detector, which for most solvents is about 10^6. The absence of a gas chromatographic column provided a quick response for all the organic compounds which, after evaporation in the injection port and dilution in the manifold, reached the detector. The injection port was maintained at 200°C and the gas chromatograph oven at 150°C. Nitrogen was used as a carrier gas at a rate of 20 ml/min.

The contents of those products which are used in aerosol form were transferred quantitatively into a plastic bag. The resulting gas and liquid phases were analyzed separately by direct injection into the above described modified gas chromatograph.

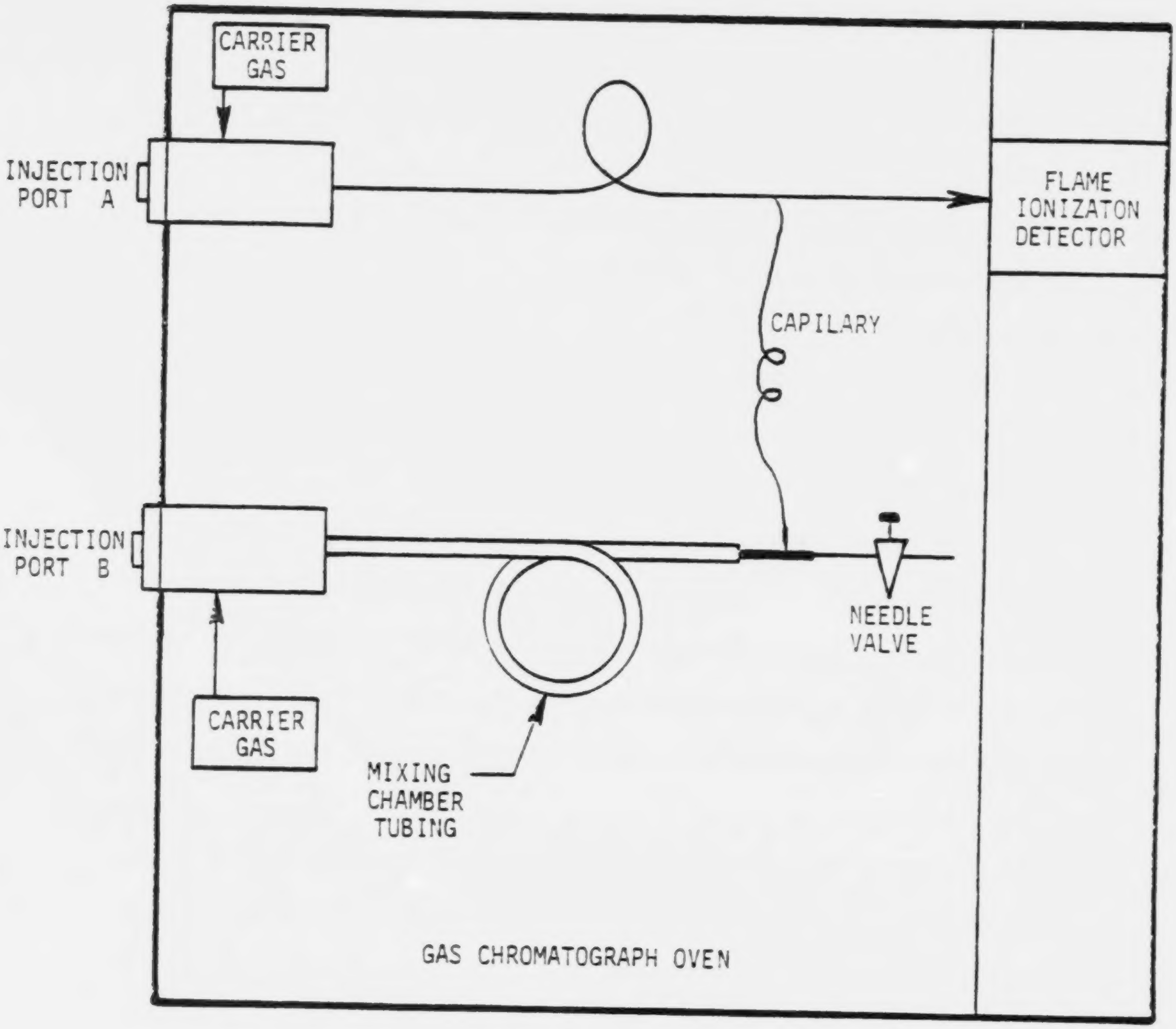

CARRIER GAS
INJECTION PORT A
FLAME IONIZATON DETECTOR
CAPILARY
INJECTION PORT B
NEEDLE VALVE
CARRIER GAS
MIXING CHAMBER TUBING
GAS CHROMATOGRAPH OVEN

FIGURE 1. Schematic presentation of the modified gas chromatograph used in determination of solvent content of various products.

Hexane was used for calibration of liquids and propane was used for gases. The differences in specific detector responses (response of the detector to the unit weight of the analyzed material) were neglected, much in the same way these differences are neglected in the conventional "Total Hydrocarbon" analysis. As a consequence, the solvent content may, in these experiments, be understated because the specific detector responses are somewhat lower for substituted hydrocarbons than for unsubstituted hydrocarbons.

4.3.2 Consumption Estimates for Categories of Consumer Products

Published information on consumption of consumer products in the individual categories was expressed in terms of dollars per year. Information on actual total weight of products consumed and on average prices for the individual categories was not available. It was thus decided to conduct a price survey on a limited scale by inspecting the prices for the products displayed on supermarket shelves.

To arrive at as realistic an average price as possible it was necessary to assign statistical weights to the individual brands and product sizes. Again, information about national market shares of consumer product manufacturers for individual product categories was not available either in published form or from direct contacts with the manufacturers. The contacted manufacturers considered market share information proprietary or unavailable.

The assignment of the relative "weights" to individual brands and product sizes was thus accomplished by observing the relative quantities of these products displayed on the shelves in the surveyed supermarkets. It was recognized that this limited scale approach suffered from shortcomings related to individual store policies and practices. In addition, the limited scope of the study required that geographical and seasonal fluctuation of the prices and product displays be neglected.

During supermarket surveys, the most representative products were bought for analysis by the above described methods. The relative proportions of display products were also used in assigning relative weights to the results of the analysis.

5.0 CONSUMPTION OF SOLVENTS BY END USE

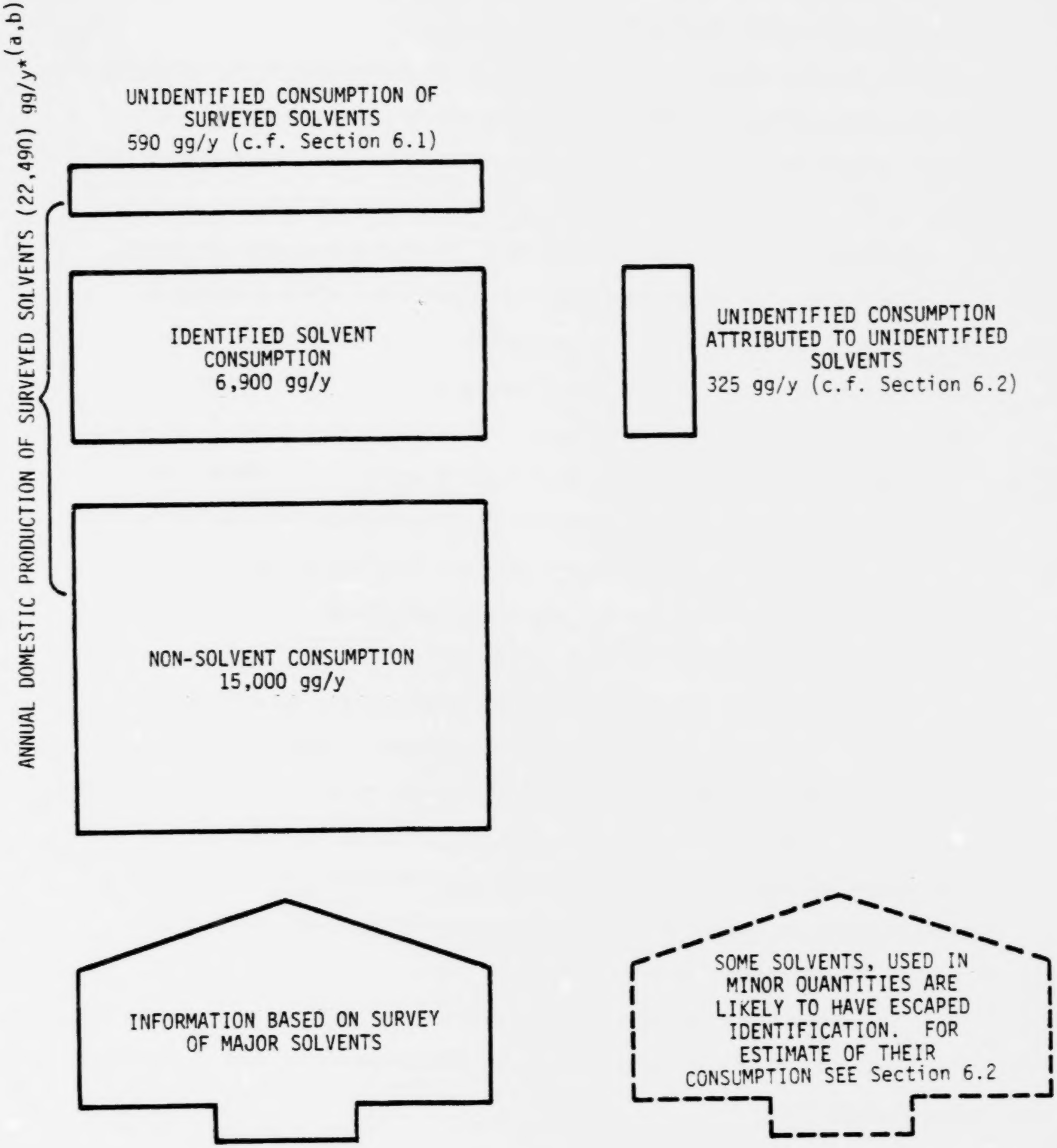
As illustrated in Figure 2, annual production of surveyed solvents amounts to 22,500 gg/y. Of this amount, 6,900 gg/y is consumed annually in strictly solvent uses in which compounds evaporate during or after the application of the solution and do not change chemically.

In addition to being used as solvents, some compounds find applications in various "non-solvent" uses. These non-solvent uses are characterized by chemical changes of the compound in question. Thus, a use of a compound as a chemical raw material or fuel does not constitute solvent use. The survey revealed that 15,000 gg/y of organic compounds are consumed in such non-solvent uses.

It should be noted, however, that this amount does not include non-solvent uses of petroleum derivatives and is, therefore, drastically understated. Petroleum derivatives find use primarily as fuels and chemical raw materials. Only a minor fraction is used as solvents. Nevertheless, due to a very large scale of production of petroleum derivatives, even this minor fraction constitutes more than one half of the total domestic solvent consumption. The non-solvent consumption is up to two orders to magnitude higher for petroleum derivatives than for all other surveyed compounds combined.

The available information was insufficient to identify end uses for 590 gg/y of surveyed solvents. The unidentified solvent consumption is actually larger because some solvents used in minor quantities are likely to have escaped identification. Thus, the identified solvent consumption was augmented by 325 gg/y to a total of 910 gg/y, in accordance with the analysis presented in Section 6.2.

Consumption of the nine most used solvents in the nine major end uses is summarized in Table 2. Both the solvents and the end uses are listed in decreasing order of domestic annual consumption.


ANNUAL DOMESTIC PRODUCTION OF SURVEYED SOLVENTS (22,490) gg/y*(a,b)
UNIDENTIFIED CONSUMPTION OF SURVEYED SOLVENTS
590 gg/y (c.f. Section 6.1)
IDENTIFIED SOLVENT CONSUMPTION
6,900 gg/y
UNIDENTIFIED CONSUMPTION ATTRIBUTED TO UNIDENTIFIED SOLVENTS
325 gg/y (c.f. Section 6.2)
NON-SOLVENT CONSUMPTION
15,000 gg/y
INFORMATION BASED ON SURVEY OF MAJOR SOLVENTS
SOME SOLVENTS, USED IN MINOR QUANTITIES ARE LIKELY TO HAVE ESCAPED IDENTIFICATION. FOR ESTIMATE OF THEIR CONSUMPTION SEE Section 6.2

(a) INCLUDING IMPORTS, EXCLUDING EXPORTS
(b) NON-SOLVENT USES OF PETROLEUM DERIVATIVES ARE NOT INCLUDED
* gg = 10^3 mt = 10^6 kg

FIGURE 2: Summary of solvent consumption breakdown into identified, unidentified, and non-solvent categories.

TABLE 2

SUMMARY OF THE DOMESTIC ANNUAL SOLVENT CONSUMPTION BY END USE

SOLVENTS	ANNUAL SOLVENT CONSUMPTION BY END USE (Gg/year*/(lb x 10^6/year))**																			
	Surface Coatings		Metal Cleaning		Adhesives		Industrial Processes		Aerosol Products		Dry Cleaning		Plastics		Graphic Arts		Rubber		Other Identified Uses	
		%(a)		%(a)		%(a)		%(a)		%(a)		%(a)		%(a)		%(a)		%(a)		%(a)
Special Naphthas	1670 (3667)	71	275 (605)	42	418 (919)	86	43 (94)	11	66 (145)	22	240 (528)		274 (602)	84	267 (587)	99	206 (455)	100	740 (1622)	43.1
Methanol							300 (660)	79											59 (130)	3.5
Isopropanol	111 (245)	4.7																	90 (198)	5.3
Ethanol							37 (82)	9.8											257 (567)	15.1
Perchloroethylene			54 (120)	8.3							45 (100)	15.							185 (407)	10.9
Methyl Ethyl Ketone	177 (390)	7.6			36 (81)	7.6													33 (74)	2.0
1,1,1 Trichloro-ethane			195 (431)	29.															13 (30)	0.8
Acetone	93 (205)	4.0																	59 (130)	3.5
Methylene Chloride			25 (55)	3.8					50 (110)	17.									101 (223)	5.9
Other Solvents	297 (655)	13.	109 (240)	17.	31 (69)	6.5	0 (0)	0	176 (388)	60.	0 (0)	0	8 (19)	3.0	3 (8)	1.3	0 (0)	0	173 (380)	10.
Total	2346 (5120)	100	658 (1449)	100	485 (1069)	100	380 (836)	100	292 (643)	100	285 (628)	100	282 (621)	100	270 (595)	100	206 (455)	100	1710 (3760)	100
% (b)	29.8%		8.4%		6.2%		4.8%		3.7%		3.7%		3.6%		3.5%		2.6%		21.9%	

* Gg = 10^6 kg = 2.2×10^6 lb

** The maximum number of significant digits justified by the reliability of the data is 2. However, some data are presented with more than two significant digits to avoid the inconvenience due to round-off error.

(a) Consumption of the individual solvents expressed as a percentage of the total consumption for the given end use.

(b) Consumption in the given end use as percentage of total solvent consumption.

One single group of solvents, special naphthas, accounts for 55% of the total solvent consumption with the next most used solvent, methanol, accounting for 5%. "Special naphthas" is a common name for all petroleum distillates used as solvents. Published information on these solvents is very incomplete and an extensive interviewing program involving producers and marketers was required. Due to their exceptional importance, special naphthas are discussed separately in Section 9.0.

Table 3 complements Table 2 by providing salient statistics for the same nine solvents. Consumption in the identified, unidentified and total solvent uses is presented for each solvent along with the total consumption which includes the combined "non-solvent" uses such as chemical synthesis, fuel, etc.

The information summarized in Tables 2 and 3 is expanded in Tables A1 and A2, presented in the Appendix. Table A1 lists end uses in decreasing order of total annual solvent consumption. Consumption of individual solvents is provided for every end use. Solvents are listed in Table A2 in decreasing order of annual usage. End use breakdown is given for each solvent. The year to which the individual solvent end use refers is also given.

5.1 Classification of Solvent Consumption Into Industrial and Consumer/Commercial Sectors

Many solvent end uses can be easily classified into what are conventionally considered industrial, commercial and consumer use sectors. However, many end uses are insufficiently clearly defined for such classification. These end uses can be classified only with the help of specific criteria. These criteria naturally depend on the use for which the classification is intended.

The major purpose of solvent end use classification in this study is to serve as a tool in the development of VOC control programs. Solvent end use information is especially helpful in preparation of regional VOC emission inventories. The most difficult

TABLE 3

SUMMARY OF THE DOMESTIC ANNUAL SOLVENT CONSUMPTION

SOLVENTS	YEAR	ANNUAL DOMESTIC CONSUMPTION (gg/year*/(lbx10^6/year)) **										
		AS SOLVENT			IN IDENTIFIED END USES			IN UNIDENTIFIED END USES			INCLUDING "NON SOLVENT" END USES	
			%(a)	%(b)		%(a)	%(c)		%(a)	%(d)		%(a)
Special Naphthas	1977	4,319 (9,501)	55.3	100	4,193 (9,224)	60.7	97	126 (277)	12.2	2.8	4,319 (9,501)	19.0
Methanol	1977	389 (856)	5.0	13	359 (790)	5.2	92	30 (66)	3.3	7.7	3,000 (6,600)	13.2
Isopropanol	1978	315 (693)	4.0	36	201 (443)	2.9	64	113 (250)	12.5	36.	877 (1,930)	3.8
Ethanol	1975	295 (649)	3.8	49	295 (649)	4.3	100	0 (0.0)	0	0.0	593 (1,305)	1.2
Perchloroethylene	1974	291 (642)	3.7	88	285 (627)	4.1	97	6 (15)	0.8	2.3	330 (728)	0.7
Methylethyl Ketone	1973	247 (545)	3.2	100	247 (545)	3.6	100	0 (0.0)	0	0.0	247 (545)	0.5
1,1,1,1 Trichloroethane	1975	209 (461)	2.7	80	209 (461)	3.0	100	0 (0.0)	0	0.0	261 (575)	0.5
Acetone	1977	186 (410)	2.4	20	152 (335)	2.2	81	34 (75)	3.8	18	931 (2,050)	1.9
Methelene Chloride	1976	176 (388)	2.3	70	161 (355)	2.2	91	15 (33)	1.7	8.5	250 (550)	0.5
Other Solvents		1,383 (3,043)	17.7		799 (1,759)	11.6	58	584 (1,284)	64.2	42	12,000	58.7
Total		7,810 (17,200)	100		6,900 (15,200)	100		910 (2,000)	100		22,800 50,100	100

* gg = 10^6 kg = 2.2 x 10^6 lb.

** The maximum number of significant digits justified by the reliability of the data is 2. However, some data are presented with more than two significant digits to avoid the inconvenience due to round-off error.

(a) Consumption of the individual solvent expressed as a percentage of the total for the column.

(b) Percentage of consumption used in strictly solvent uses.

(c) Consumption in identified uses as percentage of total solvent consumption.

(d) Consumption in unidentified end uses as percentage of total solvent consumption.

step in such inventories is data collection. Mail survey represents the most common technique used by air pollution control agencies for gathering emission inventory data. Mail survey questionnaires are typically addressed to the so called "point sources." Point sources are larger sources for which individual records are kept in the inventory files. They represent physical locations where significant quantities of VOC are released. Thus, they largely correspond to what is conventionally considered the industrial sector.

Conversely,the so called "area sources" do not correspond to any specific location but cover a wider area. They form an assembly of smaller sources dispersed in a given region. These smaller sources, therefore, largely correspond to the conventional consumer sector and to some extent to the commercial sector. An emission inventory treats them collectively.

In order that the solvent end use information can be effectively utilized in VOC control programs it was decided that the classification of end uses into industrial and consumer/commercial sectors should correspond to point source - area source classification. Thus, the industrial sector (point sources) would be covered by a typical emission inventory questionnaire, as described in reference 5, while the consumer/commercial sector (area sources) would not. Discussion of the relationship between the questionnaire point sources and industrial and commercial use sectors in presented is more detail in the Part III of this report.

5.2 End Use Classification

Classification of solvent end uses is presented in Table 4. Several of the end uses in Table 4 appear to overlap. Some narrowly defined uses appear to be already fully contained in other, more general end use categories. Thus, for example, "Extraction, Vegetable Oil," "Extraction Solvent," "Extraction, Rare Metals" and "Industrial Uses" are listed as separate end uses in the industrial sector in Table 4. Obviously, vegetable oil extraction and rare metals extraction are both extraction processes and would thus appear already contained in the "Extraction Solvent" category. The "Extraction Solvent" category appears in turn already contained in the more general "Industrial Processes" category.

TABLE 4

CLASSIFICATION OF SOLVENT END USES INTO INDUSTRIAL AND CONSUMER/COMMERCIAL USAGE SECTORS

	Nationwide Consumption gg/y (lbs x 10^6/y)*				
INDUSTRIAL USES			5,534	(12,200)	(71%)
Industrial Surface Coatings	1,820	(4,000)			
Metal Cleaning	660	(1,449)			
Adhesives, Industrial Use	465	(1,020)			
Industrial Processes	380	(836)			
Dry Cleaning	290	(638)			
Plastics	280	(621)			
Graphic Arts	270	(595)			
Rubber	210	(455)			
Resins	210	(454)			
Textiles	180	(400)			
Extraction Vegetable Oil	160	(342)			
Auto Body Refinishing	160	(352)			
Paint Removing	75	(165)			
Cleaning	74	(162)			
Acetaldehyde Process	71	(157)			
Cellulose Acetate Solvent	46	(102)			
Pharmaceutical Industry	29	(64)			
Lube Oil Refining	25	(54)			
Phillips Low Pressure Polyethylene Solvent	18	(39)			
Extraction Hardwood Pulping	15	(33)			
Electrolytic Solvent in Grignard Reaction	15	(33)			
Inks	15	(32)			
Foam Blowing	13	(28)			
Extraction, Udex	12	(26)			
Extraction Solvent	11	(25)			
Toluene Diisocyanate Process	10	(23)			
Solvent for Acetylene	10	(21)			
Extraction, Butadiene	5	(11)			
Extraction, Rare Metals	5	(10)			
CONSUMER/COMMERCIAL			1,086	(2,400)	(14%)
Architectural surface coatings	320	(707)			
Aerosol Products	292	(643)			
Household	160	(346)			
Toiletries	113	(249)			
Rubbing Compound	53	(117)			
Windshield Washing	52	(115)			
Polishes and Waxes	41	(91)			
Adhesives, non-industrial use	25	(55)			
Space Deodorant	15	(34)			
Moth Control	12	(27)			
Laundry Treatment	3	(7)			
OTHER USES			230	(508)	(3%)
Pesticides	140	(307)			
Cut-back asphalt	90	(201)			
SUBTOTAL, IDENTIFIED USES**			6,900	(15,000)	(88%)
UNIDENTIFIED USES**			900	(2,000)	(12%)
TOTAL**			7,800	(17,000)	(100%)

*gg = 10^3 mt = 10^6 kg

**rounded off to two significant figures

This apparent overlap results from the method employed in solvent consumption estimates. The available end use information was much more detailed for some solvents than for the others. Solvents for which only less detailed breakdown was available were by necessity classified into more general categories.

It is important to realize that these more general categories, as presented in Table 4, do not contain any of the solvents from the more specific categories. Reference to Tables A1 and A2 in the Appendix will resolve any ambiguities. Thus, in the above example of extraction solvents, Table A2 will show that the 11 gg/y of solvent consumed in the "Extraction Solvent" category consists exclusively of trichloroethylene. Also, all of the 4 gg/y of solvent consumed in the "Rare Metal Extraction" category correspond to a single solvent, methylisobutyl ketone, while special naphthas account for all of the 160 gg/y of solvent consumed in the vegetable oil extraction. Obviously, neither special naphthas nor methylisobutyl ketone are included in the more general category of "Extraction Solvents," which consists entirely of trichloroethylene.

Similar problems of end use overlap can be noticed in the consumer/commericial category. Thus, solvent use in "Toiletries" and Cleaning" appears to overlap with the "Aerosols" category and all of these categories are in an apparent overlap with the "Household" category. Again, reference to Table A1 will show that although many other solvents are contained in household products, the 160 gg/y of solvent from the "Household" category in Table 4 consists exclusively of special naphthas (120 gg/y) and isopropanol (40 gg/y).

The information on solvent end uses published in literature is based primarily on surveys of solvent manufacturing and marketing establishments. This information refers largely to the quantities of solvent sold to various industries. In some cases the sale/purchase information is insufficient to identify those processes, industries or products which are directly associated with actual solvent use and release to the atmosphere. Thus, the primary purchaser of solvents could manufacture a solvent containing product and sell it to other industrial establishments where the solvent would actually be released. He could also sell his product to retail distributors for use by consumers. In these cases identification and classification of the solvent releasing step requires thorough knowledge of all the industries involved.

As in every attempt at classification, a few borderline cases were found which in a certain sense could not be considered purely solvent uses. The following four cases illustrate the point:

aerosol products	(312 gg/year; 687 lbs x 10^6/year)
foam blowing	(13 gg/year; 28 lbs x 10^6/year)
space deodorants	(15 gg/year; 27 lbs x 10^6/year)
moth control	(12 gg/year; 27 lbs x 10^6/year)

Aerosol products, by far the largest in the above group do, in a chemical sense, represent a solvent system in which the propellant is in solution (occasionally partial solution - emulsion) with the other active and inactive ingredients of the product, although its primary function may not be to serve as a solvent.

5.3 Variation in Annual Solvent Consumption

As explained in the Methodology section, the solvent end use estimates were occasionally arrived at by combining information from several sources. This information may have referred to a few different years. The most recent consumption and end use data were complemented, when needed, with older information.

Such updating of end use data obviously presupposes that the usage pattern has not significantly changed during the period in question. For certain solvents, such as those subject to emission restrictions imposed by environmental protection agencies (e.g., the widely applied Los Angeles Rule 66),[6] the usage pattern may have changed considerably. An indication of such change in usage pattern can sometimes be found in the changes in the annual consumption. For the solvents subject to environmental emission restrictions the total consumption rate may decline. This decline may be offset by a corresponding increase in consumption of another solvent.

This is illustrated by the following changes in the annual consumption of trichloroethylene and trichlorethane as cleaning solvents:

YEAR	CONSUMPTION (gg/y)	
	1971	1974
trichloroethylene	200	160
trichloroethane	110	170

A more recent example is offered by the replacement of fluorocarbons with saturated low molecular weight hydrocarbons as aerosol propellants. This change was precipitated by a finding that due to their chemical inertness, fluorocarbons could resist oxidative changes in the atmosphere long enough to reach the ozone layer in the stratosphere. This may have resulted in a depletion of ozone which provides an essential shield against the sun's ultraviolet radiation.

Whenever possible in the process of interpolation, data were reviewed for possible indications of changes in solvent consumption patterns. Changes of consumption for major solvents through the years 1974 to 1978 and the anticipated changes until 1982 are shown in Figure 3.

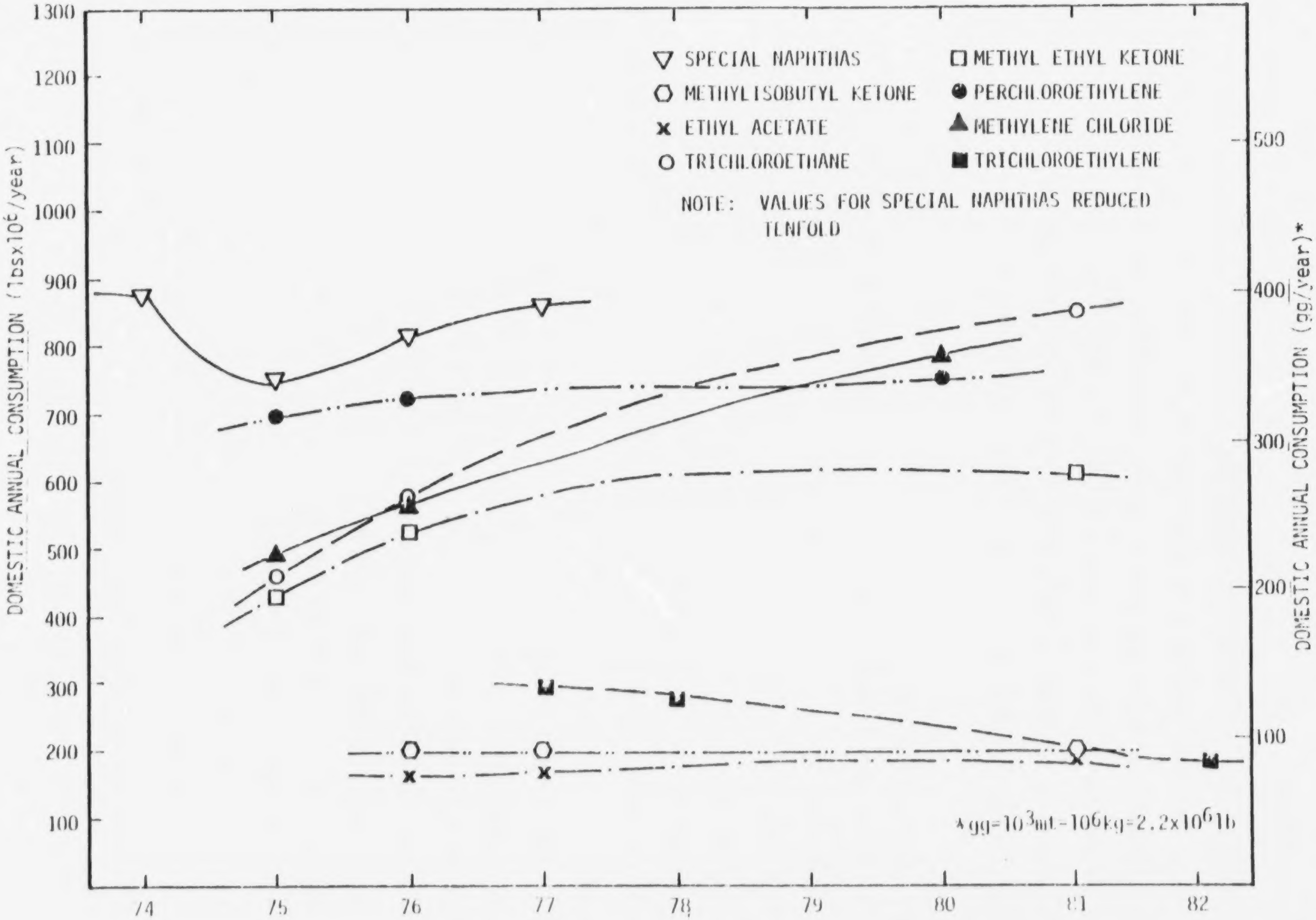


FIGURE 3. Domestic annual consumption of some major solvents.

6.0 UNIDENTIFIED SOLVENT CONSUMPTION

As illustrated in Figure 2, the unidentified solvent consumpion consists of two parts: unidentified consumption of surveyed solvents and unidentified consumption attributed to the unknown solvents used in minor quantities. The total unidentified consumption is estimated to be 910 gg/y (2,000 x 10^6 lbs/y). Of this amount, 590 gg/y (1,300 x 10^6 lbs/y) belongs to unidentified consumption of the surveyed solvents.

6.1 Surveyed Solvents

Consumption in unidentified uses was determined individually for each surveyed solvent on the basis of the available information of that solvent's end uses, often from more than one source. Literature information on end use breakdown for individual solvents would sometimes be complete. Frequently, however, the breakdown would list only the major end uses, describing the remaining consumption as "other uses." Ethyl acetate and methylethyl ketone provide examples of such incomplete end use breakdown in Tables 5 and 6.

The "other uses" clearly constitute unidentified consumption. However, not all of this unidentified consumption does necessarily correspond to strictly solvent use as defined in this report (cf. Definition Section). Some of it may be in non-solvent end uses. Therefore, decision had to be made regarding the character of the unidentified consumption. Clearly, grouping all of the unidentified consumption into either strictly solvent or non-solvent uses would produce an error.

One possible solution to this problem, which in our opinion reduces the overall error, is to allocate the unidentified consumption as shown in Figure 4. This figure shows end use breakdown for methylene chloride.[2] Sixty five percent of total methylene chloride produced is consumed in identified solvent end uses: paint removing, aerosols, metal cleaning and pharmaceuticals manufacture. Twenty five percent is consumed in various

TABLE 5

ILLUSTRATION OF INCOMPLETE SECONDARY INFORMATION ON END USE BREAKDOWN - ETHYL ACETATE[2]

Solvent		97%
Surface Coatings	65%	
Plastics	12%	
Miscellaneous	20%	
Chemical Synthesis		3%

TABLE 6

ILLUSTRATION OF INCOMPLETE SECONDARY INFORMATION ON END USE BREAKDOWN - METHYLETHYL KETONE[2]

Vinyl Coatings	34%	
Nitrocellulose Coatings	14%	
Adhesives	14%	
Acrylic Coatings	12%	
Miscellaneous Coatings	7%	
Lube Oil Dewaxing	7%	
Miscellaneous and Exports		12%

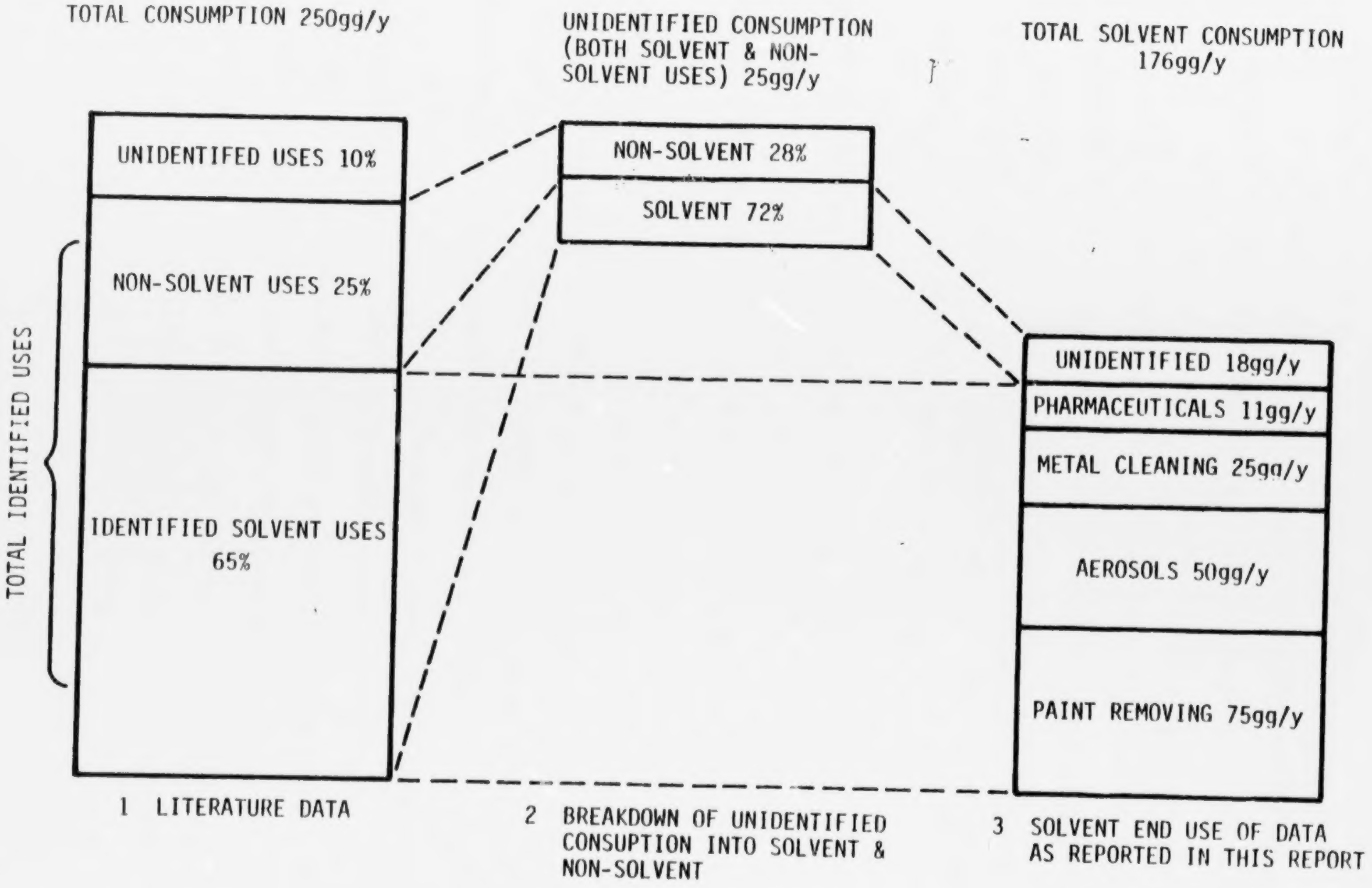

TOTAL CONSUMPTION 250gg/y
UNIDENTIFED USES 10%
NON-SOLVENT USES 25%
IDENTIFIED SOLVENT USES 65%
TOTAL IDENTIFIED USES
1 LITERATURE DATA
UNIDENTIFIED CONSUMPTION (BOTH SOLVENT & NON-SOLVENT USES) 25gg/y
NON-SOLVENT 28%
SOLVENT 72%
2 BREAKDOWN OF UNIDENTIFIED CONSUPTION INTO SOLVENT & NON-SOLVENT
TOTAL SOLVENT CONSUMPTION 176gg/y
UNIDENTIFIED 18gg/y
PHARMACEUTICALS 11gg/y
METAL CLEANING 25gg/y
AEROSOLS 50gg/y
PAINT REMOVING 75gg/y
3 SOLVENT END USE OF DATA AS REPORTED IN THIS REPORT

FIGURE 4: Illustration of a breakdown of unidentified consumption into solvent and non-solvent fractions - data for methylene chloride.(2)

non-solvent end uses, leaving ten percent unidentified. This 10% is most likely consumed in both solvent and non-solvent uses. It was now assumed that the fraction of the unidentified consumption which corresponds to strictly solvent end uses is equal to the fraction of the identified consumption in solvent end uses.

In the above example, 72% of the total identified consumption takes place in solvent end uses and 28% in non-solvent end uses. Therefore, it is assumed that 72% of the unidentified 25 gg/y also takes place in solvent end uses. This amounts to 18 gg/y. Thus, the final end use breakdown for methylene chloride, as presented in this report, consists of a total of 160 gg/y of identified solvent consumption and 18 gg/y of unidentified solvent consumption.

Table 7 lists the solvents in decreasing order of the unidentified consumption. Throughout the study this table underwent numerous revisions. The unidentified solvent usage is currently very large for isopropanol. On the basis of secondary information the unidentified solvent usage for this alcohol was found to be 20 gg/y (450 lbs x 10^6/y). This number was reduced to the current value of 110 gg/y (250 lbs x 10^6/y) on the basis of the information supplied by the major producers of isopropanol. Further reduction of the unidentified usage for this solvent by means of marketing information would be very difficult due to a) numerous end uses and b) the fact that most of the alcohol destined to "miscellaneous" usage is distributed by a large number of distributors.

Although the unidentified usage for methanol is listed as only 30 gg/y (67 lbs x 10^6/y), it is important to note that a large portion of the usage of this solvent 300 gg/y (660 lbs x 10^6/y) is in the broad "industrial processes" category. Industry sources estimate that 80% of methanol reaches its end users through numerous distributors which makes any finer categorization of its industrial usage extremely difficult.

TABLE 7

CONSUMPTION OF SOLVENTS IN UNIDENTIFIED END USES

Solvent	gg/y*	(lb x 10^6/y)	%$^{(a)}$
Special Naphthas	126	(277)	13.9
Isopropanol	114	(250)	12.5
Butyl Alcohols	45	(100)	5.0
Chloro Benzene	45	(99)	5.0
Acetone	34	(75)	3.8
Glycol Ethers	30	(66)	3.3
Methanol	30	(66)	3.3
Tetrahydrofuran	22	(49)	2.5
Fluorocarbons	21	(47)	2.4
Ethyl Benzene	18	(40)	2.0
Isopropyl Acetate	18	(40)	2.0
Methylene Chloride	15	(33)	1.7
Triethylamine	13	(29)	1.5
Methyl Isobutyl Ketone	9	(20)	1.0
Triethylene Glycol	8	(18)	0.9
Perchloroethylene	7	(15)	0.8
Amyl Acetates	5	(12)	0.6
Trichloroethylene	5	(10)	0.5
Ethylene Dichloride	4	(8)	0.4
O-Dichlorobenzene	3	(7)	0.4
P-Dichlorobenzene	3	(7)	0.4
Nitrobenzene	2	(5)	0.3
Diethylene Glycol	1	(2)	0.1
Furfural	0	(0)	0
Cyclclohexanone	0	(0)	0
Cylclohexanol	0	(0)	0
Butyl Acetates	0	(0)	0
Ethyl Acetate	0	(0)	0
Methyl Ethyl Ketone	0	(0)	0
1, 1, 1, Trichloroethane	0	(0)	0
Ethanol	0	(0)	0
Subtotal for All Surveyed Solvents	589	(1,275)	63.7
All Other Solvents	325	(725)	36.3
Total	910	(2,000)	100

(a) Percentage of total solvent consumption in unidentified end uses.

*gg = 10^3 mt = kg = 2.2 x 10^6 lb.

The unidentified solvent usage for special naphthas stands currently at 126 gg/y (277 lbs x 10^6/y). As seen in Table 3, special naphthas account for 55% of total domestic solvent consumption. For comparison, the second most largely consumed solvent, methanol, represents only 5% of the total solvent usage, more than ten times less than the special naphthas. This large consumption coupled with the fact that at the outset of this study about 60% of it was classified into the unidentified usage category,[7] resulted in a special effort devoted to identification of end uses for special naphthas. The results are presented in Section 9.0.

6.2 Unidentified Solvents

Due primarily to their small consumption , some solvents were not identified in the survey. Therefore, the total unidentified consumption of all solvents is larger than estimated on the basis of the surveyed solvents. The actual extent of this underestimate is very difficult to assess.

Distribution of solvent consumption, graphically presented in Figure 5, provides a helpful insight into the problem and offers some basis for its resolution. The solvents in the figure are ranked by increasing consumption. The cumulative consumption is then presented as a function of the number of solvents surveyed. The figure shows that the first twelve solvents account for 280 gg/y. These twelve solvents represent 44% of the total number of the surveyed solvents. If this 44% of the surveyed solvents were not identified in the course of the survey, the total solvent consumption would have been underestimated by only 280 gg/y, or about 4%.

Based on this analysis we used 325 gg/y to approximate the underestimate of the unidentified solvent consumption attributed to the unidentified solvents. It is likely that these unidentified solvents are consumed in smaller quantities than the identified solvents. Therefore, the number of unidentified solvents covered by our estimate of 325 gg/y is likely to be sufficiently large and consequently the unidentified solvent consumption appears adequately approximated.

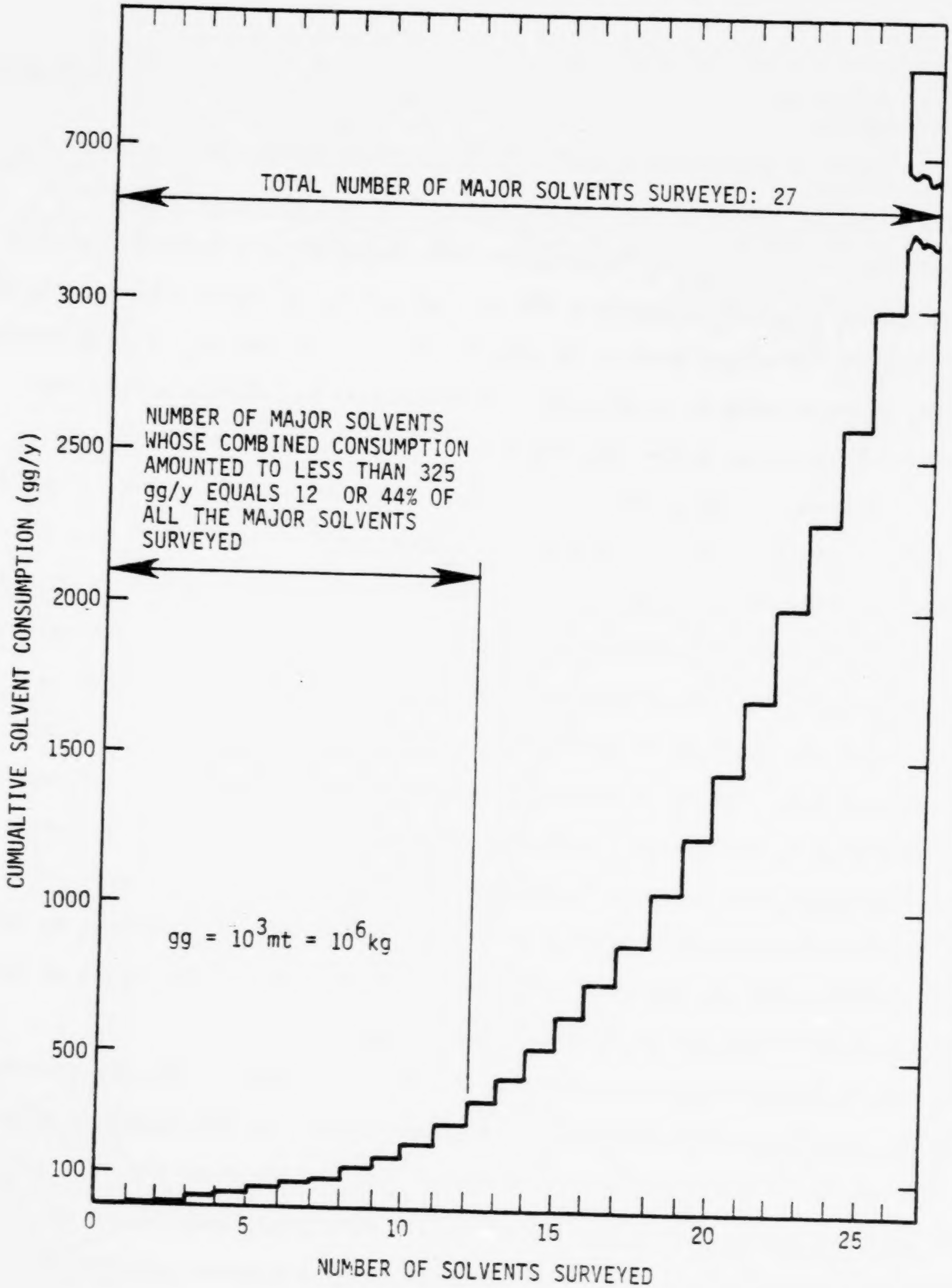


FIGURE 5: Cumulative distribution of solvent consumption by number of solvents.

6.3 Allocation of Unidentified Solvent Consumption Into Industrial and Consumer/Commercial Sectors

The unidentified solvent consumption poses a problem with regard to a solvent emission inventory. The question is whether this unidentified solvent consumption should be treated as area sources (and allocated on a per capita basis) or as both area and point sources. If this latter alternative is adopted, then the relative amount of solvent consumption related to area and point sources must be determined. In addition, it must be decided how to proportionate the unknown solvent consumption to the individual point sources. The available solvent end use information is insufficient to answer these questions.

A partial solution to this difficult problem may nonetheless be possible. No matter how the unidentified solvent consumption is treated, it will cause an error in solvent emission inventory. The proper question to ask is therefore: How can this error be minimized. When answering this question an important point should be kept in mind. In most industrial as well as in most consumer/commercial applications, solvents are used as mixtures. It is reasonable to assume that the unidentified solvent consumption largely corresponds to minor solvent components in such mixtures both in industrial and consumer/commercial applications. It is likely that in the average the unidentified minor components of solvent mixtures are used in the industrial and consumer/commercial applications in the same proportions as the major components of these mixtures. Therefore, the unidentified solvent consumption should be proportioned between the area sources and the point sources in the same way as the identified solvent consumption.

In reality, these proportions may be considerably different and the assignment of the unidentified solvent consumption to the industrial and consumer/commercial sectors in this manner will very likely produce an error. However, we believe that as far as an emission inventory is concerned, this error will be significantly smaller than if the entire unidentified solvent consumption was treated as an area source and allocated on a per capita basis.

Solvent consumption in pesticides and cutback asphalt should not be considered in the above analysis because both of these end uses involve almost exclusively special naphthas and, therefore, will not contain any portion of the unidentified solvent consumption.

According to Table 4, about 80% of the identified solvent consumption takes place in the industrial sector, which corresponds to the point sources, and 20% in the consumer/commercial sector corresponding to the area sources. By analogy then, 80% of the 900 gg/y of the unidentified solvent consumption should also take place in the industrial sector. This amounts to about 700 gg/y. The remaining 200 gg/y should therefore be associated with the consumer/commercial sector.

Solvent consumption in some of the industries and processes in the industrial sector, presented in Table 4, is understated. This is because some of the solvents used in these industries in minor quantities were not identified. A portion of the 700 gg/y therefore corresponds to these solvents. In addition, some of the minor industrial uses were not identified. They account for the remainder of these 700 gg/y of unidentified solvent consumption.

The present data are insufficient to allocate the unidentified industrial solvent consumption to specific industries and processes. Fortunately, this is not likely to interfere with emission inventories since it is expected that most of the unidentified solvent consumption will be adequately covered by the industrial solvent use questionnaires.

In summary, point sources will account for 80% of the total solvent consumption and area sources for 17% as shown in Table 8. The remaining 3%, corresponding to "Other Uses" (pesticides and cutback asphalt) should be allocated by special techniques. One way of obtaining information on regional levels of use of pesticides and cutback asphalt is to contact regional agricultural and transportation government agencies or institutions. Statistical information on sales of pesticides may prove valuable.

TABLE 8

SUMMARY OF SOLVENT END USE CLASSIFICATION WITH UNIDENTIFIED CONSUMPTION ALLOCATED TO INDUSTRIAL AND CONSUMER/COMMERCIAL SECTORS

	Consumption gg/y (lbs x 10^6/y) (a), (b)		
Industrial Uses (Point Sources)	6,200	(14,000)	80%
Consumer/Commercial Uses (Area Sources)	1,300	(2,900)	17%
Other Uses (Special Sources)	200	(500)	3%
TOTAL	7,800	(17,000)	100%

(a) gg = 10^3 mt = 10^6kg

(b) rounded off to 2 significant figures

7.0 COMPLETENESS OF SURVEY

Perhaps the best way to estimate the completeness of this survey is to employ methodology different from the one used here and then compare the results. If the results are in agreement, it is quite likely that the estimates by both approaches were accurate. This is because it is unlikely that same error would be counted by the two sufficently different and independent approaches. It appears that the most meaningful such complementary approach would start from the individual end uses, as compared to the individual solvents as it was done here.

Solvents usage data would first have to be accumulated by a survey of a given industry. Regression analysis could then be applied on the data obtained from the individual plants to provide some basic relationships characterizing the industry. The essence of such a relationship is to correlate solvent consumption with convenient statistical parameters characterizing the industry. One such convenient relationship is solvent consumption or emission per employee in a given industry. Other relationships have been developed such as consumption of gas, electricity, water, etc., as related to solvent consumption.[8] Once these relationships are determined, statistical data can be used to arrive at regional or national solvent consumption in that industry. If these projections agree with the consumption estimates based on solvent survey, it is quite likely that both estimates are accurate.

The EPA has conducted independent surveys of some major solvent end uses. The good agreement of their findings with ours, as shown in Section 8, is an indication that the survey was complete.

8.0 COMPARISON OF SOLVENT END USE STUDIES

Table 9 provides comparisions of the results of four solvent end use studies.[1,7,8,9] In addition to solvent consumption in the major end uses, the table lists total solvent consumption and fractions of this consumption in identified and unidentified end uses. Three of the four studies refer to the period before 1972.[7,8,9] The fourth one[1] appeared in 1978 and contains recent EPA estimates on sources of volatile organic emissions. These estimates were in part based on systematic studies by EPA of some selected major end uses of solvents.

Comparision of the data in Table 9 reveals a varying degree of agreement from one end use to another. The disagreement between various studies could be related to the degree of their completeness. In studies based on surveys of solvent production and marketing information, the disagreement between various studies can be expected to increase for those uses where a small number of solvents are used. If any of the solvents is overlooked, the resulting value will change considerably. Also, solvents with lower total usage are most likely to be overlooked.

Those end uses employing large amounts of solvents, especially those solvents with larger total consumption should show less variation from study to study. The variation will then primarily reflect differences in end use estimates for the individual solvents.

Although a comparision of only three estimates does not provide sufficient statistical basis for evaluation of errors, some qualitative conclusions can still be drawn. Therefore, the maximum range of the three older estimates for a given end use was expressed as a percentage of their average, and also listed in Table 9. The disagreement between the estimates measured in this way suggests that the results may very well contain an error of ±50%.

TABLE 9a
COMPARISON OF SOLVENT END USE ESTIMATES

	Annual Solvent Consumption (gg/y; (lbsx10^6))*			
	Ref. 7 (Walden) 1971	Ref. 8 (MSA) 1972	Ref. 9 (Kirk-O.) 1966	% (a)
Total Solvents Produced	20,300 (44,700)			
Consumption as Solvent	6,700 (14,300)	6,500 (14,270)	5,500 (12,000)	
Consumption in Identified Solvent Uses	3,000 (6,700)	4,250- 5,750** (9,350-12,650)		
Consumption in Unidentified Solvent Uses	3,700 (8,100)	740- 2,200** (1,620- 4,920)		
END USES				
Surface Coatings	1,600 (3,600)	2,700- 3,600** (6,000- 8,000)	1,800 (4,000)	70%
Metal Cleaning	400 (870)	590- 860** (1,300- 1,900)	450 (1,000)	21%
Dry Cleaning	440 (970)	230- 360** (500- 800)	910 (2,000)	86%
Graphic Arts	400 (890)	160- 200** (350- 450)		76%
Plastics	160 (360)	540- 680** (1,200- 1,500)		116%
Rubber				

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* gg=10^3 mt=10^6 kg=2.2x10^6 lb

** Average used in calculation of % (a)

(a) Maximum range of values reported in Ref. 7, 8, 9, as percentage of the average.

TABLE 9b

COMPARISON OF SOLVENT END USE ESTIMATES

	Annual Solvent Consumption gg/y (lbs x 10^6/y)*							
	Ref. 1 (Radian, EPA Estimates) 1977			This Study			Difference[(a)]	
								%[(b)]
Total Solvents Produced						(50,100)		
Consumption as Solvent		8,400**	(18,600)		7,760	(17,700)	-740	-8
Consumption in Identified Solvent Uses		5,500	(12,200)		6,850	(15,100)	1,350	24
Consumption in Unidentified Solvent Uses		2,900	(6,400)		910	(2,000)	-1,990	-0.69
END USES								
Industrial Uses		4,540	(9,990)		5,530	(12,200)	900	22
Industrial Surface Coating	1,900			1,820				
Metal Cleaning	680			660				
Adhesives, Industrial Use	210			465				
Industrial Processes	1,000			380				
Dry Cleaning	230			290				
Plastics	(c)			280				
Graphic Arts	380			270				
Rubber	140[(c)]			210				
Resins				210				
Textiles	(c)			180				
Other Identified Industrial Uses				765				
Consumer/Commercial		320	(700)		1,090	(2,400)	700	240
Architectural Surface Coatings	320			320				
Aerosol Products				292				
Household				160				
Toiletries				113				
Other Identified Uses				205				
Other Uses		660	(1,450)		230	(510)	-430	-65
Pesticides				140				
Cutback Asphalt	660			90				

*gg = 10^3 mt = 10^6 kg = 2.2 x 10^6 lb.

**Includes "non-solvent" volatile organic compounds emissions.

(a) Estimate from this study minus estimate from Reference 1.

(b) Difference as percentage of estimate from Reference 1.

(c) This value is included in the industrial processes total of 1,000 gg/y.

An important source of secondary information on solvent consumption places the error of end use estimates closer to 10%.[10] It should be noted that reference 8 actually lists a range of values for each end use consumption. An uncertainty ranging from 50% to 110% is thus implied.

On the basis of the results of this study, we feel that the most significant cause of the discrepancy between the end use estimates in various studies lies in the differences in assessment of end uses of special naphthas. Special naphthas constitute the single most dominant solvent in many end uses. Some of these end uses, however, may represent a minor fraction of total consumption of special naphthas and are thus more likely to be estimated with less reliability. While finding it too difficult to specify the error of estimate, we believe that errors of ±50% for some end uses are possible.

The two more recent estimates in Table 9 (this study and the current EPA estimates[1]) show good agreement for the major end uses. The estimates were at least partially obtained in different ways (approach starting with individual solvent information vs. approach concentrating on selected end uses). As expected, the agreement between the uses with lower total consumption and those which are less clearly defined is not as good.

Reference 1 places total volatile organic emissions from industrial processes at 1,000 gg/y (2,200 lbs x 10^6/y). Solvent usage in the industrial processes is not stated explicitly. The findings of this study indicate that a large fraction of the unidentified solvent consumption in the current EPA estimates may in fact belong to various industrial processes.

9.0 SPECIAL NAPHTHAS

Since special naphthas account for such a large fraction of the total solvent consumption, the accuracy in estimates of their total consumption and of its end use breakdown will have a strong impact on the reliability of estimates for most solvent end uses. The following factors make production, sales and end use assessment for special naphthas especially difficult:

- nature of production of special naphthas as a minor fraction of total production of petroleum products;
- absence of reported data on solvent uses;
- inconsistent nomenclature which in turn makes it difficult to clearly and unambiguously specify reporting requirements;
- incomplete and inconsistent producer records on production and end uses;
- marketing of a portion of the total production through distributions.

Some of these factors will now be discussed in more detail.

Special naphthas constitute a part of naphtha, the major liquid fraction from the primary distillation process. The fraction of naphtha diverted for solvent use is quite variable. It depends on the market situation for major naphtha derived products such as gasoline or raw materials for petrochemicals, since all of these compete for the same stock. For instance, toluene and xylenes with their excellent antiknock properities are now increasingly diverted into use as gasoline ingredients. This reflects the fact that the U.S. automobile fleet contains an ever increasing number of vehicles requiring unleaded gasoline. Special naphthas account for only less than 1% of the total annual consumption of petroleum products. Thus, their marketing and the associated end use studies appear to be receiving proportionately less attention by the producers.

Published data on special naphthas production and demand are almost entirely limited to government reports. A few industry and industry association sponsored studies were also conducted but only a limited amount of this information is available. Some of these studies were concerned only with a given portion of special naphthas such as aliphatic naphthas or only with particular end use such as surface coatings.

The Department of Energy issues monthly reports on supply, demand and stock of crude petroleum, petroleum products and natural gas liquids which include information on domestic demand, production, stocks, imports, and exports for special naphthas.[11] No end use breakdown for special naphthas is provided.

There are more than 100 individual solvent mixtures consisting of petroleum distillates and marketed by various companies under different designations. For ease of communication, these products are loosely grouped into categories. These categories are not precisely defined. It appears that the following three categories offer the most practical and universal categorization scheme for special naphthas:

- aliphatic naphthas include those solvent mixtures which consist predominantly of aliphatic hydrocarbons. More highly purified aliphatic hydrocarbons such as hexanes, heptanes, mixture of hexanes and heptanes are not included, as they form a separate group of paraffinic naphthas.
- paraffinic naphthas consist of paraffins purified to a higher degree than the aliphatic naphthas. Included here are hexane, heptane, pentane, butane, and specified mixture of these compounds;
- aromatic naphthas include primarily toluene and xylenes as well as solvent mixtures in which aromatic hydrocarbons dominate.

Section A of the reporting instructions issued by the Department of Energy[12] requires special naphthas to be reported as follows:

> Special Naphtha Blending Agents. Components for special naphtha blending produced within the refinery should be reported as production of individual components such as butane, isobutane, pentane and alkylates. Report benzene, toluene, xylene as a production of special naphtha at the time these stocks are physically blended with special naphtha stocks or their final disposition is known to be that of a special naphtha blending agent. Do not report benzene, toluene, xylene as a production of special naphtha unless these conditions are met.

Section 051 of the Product Description section of that document defines special naphthas as:

> All finished products within the gasoline range, specially refined to specified flash point and boiling range, for use as paint thinner, cleaners, and solvents, including commercial hexane in conforming with ASTM Specification D1836 and cleaning solvent conforming to ASTM Specification D484. Excludes naphthas to be blended or marketed as motor gasoline, aviation gasoline, or used as petrochemical and substitute natural gas (SNG) feedstocks.

In our study the term special naphthas includes all of the petroleum distillates used as solvents. Thus, aromatic naphthas other than toluene and xylenes, which are not specifically mentioned in the above Department of Energy definition, are included in our term. To avoid confusion, the individual constituents of the special naphthas such as aliphatic, paraffinic, aromatic naphthas, xylene, toluene, hexane, heptane, cyclohexane, etc., are reported together as special naphthas. Their individual consumption and end uses are discussed in this section but in the major data tables (Tables 2, 3, A1 and A2) they are reported collectively as special naphthas.

Our contacts with numerous people in production and marketing of petroleum products revealed some inconsistency and confusion regarding the term special naphthas. Although naphtha was found universally recognized as the major liquid fraction in petroleum distillation, the term special naphthas, as a designation for strictly solvent use of naphtha fractions, was less familiar.

9.1 Primary Information Gathering

TRC inquiry into end use breakdown for special naphthas proceeded through direct contacting of producers and distributors. The producers and distributors were identified from information published in various directories[13],[14] and through direct contacts with the already identified producers.

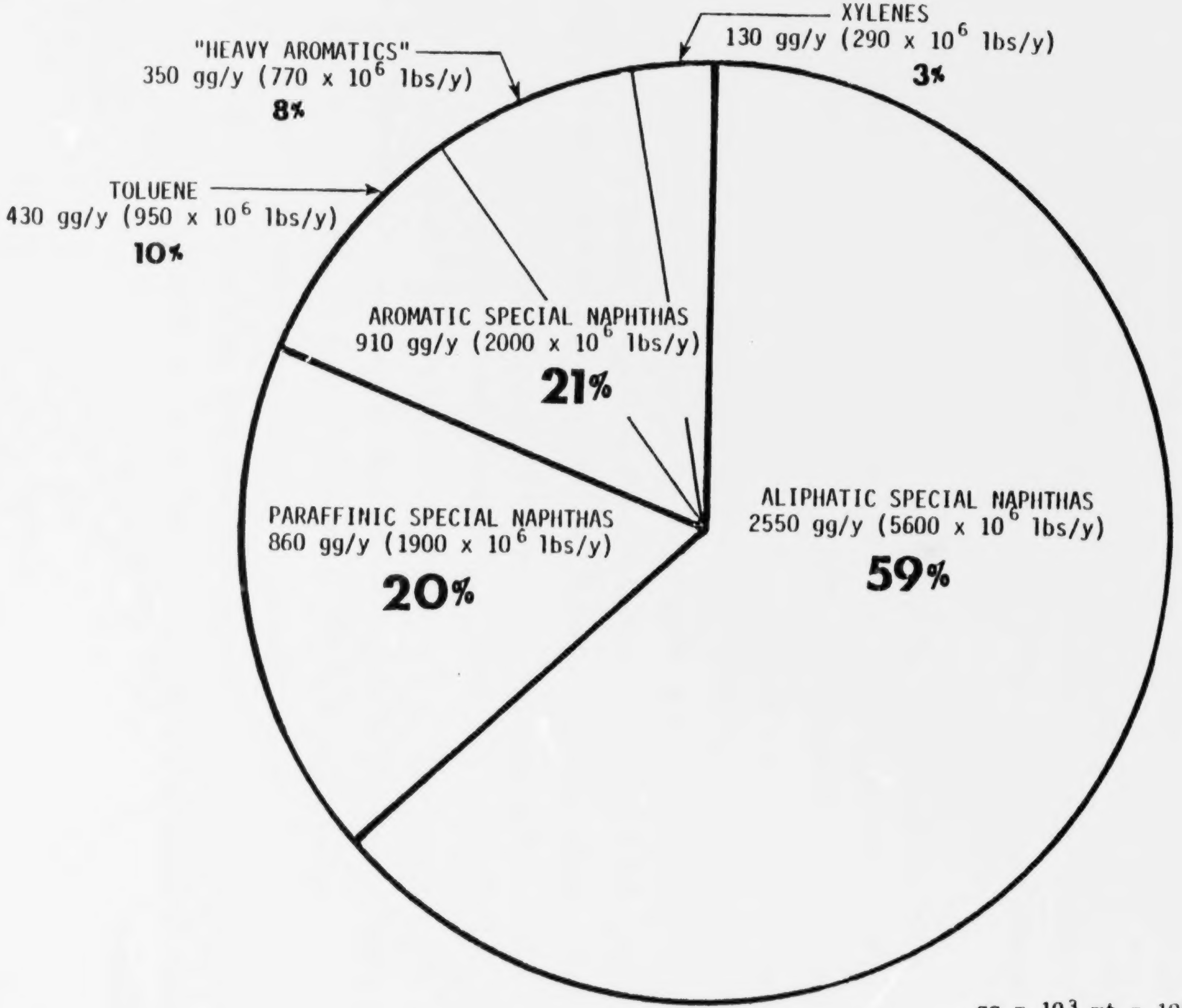
About one third of the entire U.S. domestic consumption of special naphthas was accounted for directly through detailed end use breakdowns supplied by some of the contacted companies. Other companies provided information on their total production and/or sales of aliphatic, paraffinic, and aromatic special naphthas. Some of the contacted people were able to provide end use breakdown for the entire domestic production of certain categories of special naphthas. This information originated in the studies conducted or sponsored by industry. All of this information was incorporated into the final end use breakdown reported in this study.

9.2 Total Production of Special Naphthas

As mentioned earlier the most comprehesive ongoing survey of production of special naphthas is conducted by the department of Energy.[12] The information on the domestic demand of special naphthas is received monthly from all major producers.

Our estimate of the special naphtha consumption was obtain independently from the government data by combining information from several sources. These include a study on end uses of aliphatic and aromatic special napthas not containing xylene and toluene by a private research firm,[15] industry estimates on consumption and end use breakdown of paraffinic special naphthas, and the consumption and end use information supplied to us by the individual producers and marketers of special naphthas.

Consumption of special naphthas was thus estimated at 4320 gg/y (9500 lbs x 10^6). This is 10% higher than the value reported by the Department of Energy. Considering the ambiguities in definitions of special naphthas and other earlier discussed factors which affect the reliability of the estimates for special naphthas, the agreement of our estimate with the Department of Energy data can be considered good. The breakdown of special naphtha consumption into aliphatic, paraffinic, and aromatic fractions is illustrated in Figure 6.



gg = 10^3 mt = 10^6 kg = 2.2 x 10^6 lb

FIGURE 6. Composition of special naphthas.

9.3 End Use Breakdown

The final end use breakdown for special naphthas reported in this study was based on a combination of all the available information. Specifically, this information consisted of the following:

1. end use information obtained by TRC directly from the contacted manufacturers and marketers of special naphthas;

2.(a) results of a nationwide study of end uses of combined aliphatic and aromatic special naphthas which did not include toluene and xylenes, conducted by a private research organization;[15]

(b) information on nationwide consumption and end uses of paraffinic special naphthas obtained from an industry source;

(c) combined information from TRC primary survey and limited secondary information on end uses of toluene and xylenes.

The end use breakdown for each of the above sources is presented in Table 10. Table 11 provides end use breakdown for three producers of different size.

TABLE 10

CONSUMPTION OF SPECIAL NAPHTHAS BY END USES*

Solvent End Use	Annual Solvent Consumption							
	Aliphatic and Aromatic** Naphthas$^{(a)}$		Paraffins$^{(b)}$		Toluene$^{(c)}$		Xylene$^{(c)}$	
	gg/y (lbx10^{6}/y)	%$^{(d)}$	gg/y (lbx10^{6}/y)	%$^{(d)}$	gg/y (lbx10^{6}/y)	%$^{(d)}$	gg/y (lbx10^{6}/y)	%$^{(d)}$
Surface Coating	884 (1945)	35			264 (581)	66	65 (142)	56.6
Metal Cleaning	253 (556)	10	77 (169)	9.1				
Dry Cleaning	151 (333)	6						
Graphic Arts	227 (500)	9.0			68 (149)	16.8	4 (9)	3.6
Rubber	164	6.5			11 (25)	2.8		
Plastics	38 (83)	1.5	295 (648)	35	10 (23)	2.6	4 (9)	3.6
Extraction, Vegetable Oil			151 (332)	17.9				
Adhesives	224 (494)	8.9	224 494	26.7	10 (23)	2.6		
Asphalt	68 (150)	2.7						
Insecticides	104 (228)	4.1	30 (65)	3.5			29 (65)	25.9
Household	104 (228)	4.1						
Polishes and Waxes	30 (67)	1.2						
Industrial Processes					31 (69)	7.8	12 (26)	10.4
Pharmaceutical Industry					5 (10)	1.1		
Resins	172 (378)	6.8						
Aerosol Products			66 (146)	7.9				
Unidentified Solvent Uses	99 (217)		(0)		13 (28)		(0)	
TOTAL	2518 (5540)	100	843 (1850)	100	411 (900)	100	114 (251)	100

* Note: This information was combined with information supplied by the individual producers into the final end use assessment for special naphthas, presented in Table A2 in the Appendex.

** aromatic naphthas not including toluene and xylenes

(a) information from Reference 13

(b) industry estimate

(c) combined information supplied by individual surveyed companies and secondary information

(d) consumption in a given end use as percentage of total consumption

TABLE 11

END USE BREAKDOWN OF SPECIAL NAPHTHA SALES BY THREE PRODUCERS OF DIFFERENT SIZE (%)

Solvent End Use	Total Sales less than 200 lbs x 10^6	Total Sales 200-800 lbs x 10^6	Total Sales more than 800 lbs x 10^6
Surface Coatings	54.5	72.7	64.8
Metal Cleaning	3.3	0.5	0.4
Dry Cleaning	18.0	—	21.2
Graphic Arts	13.6	4.8	0
Rubber	3.9	2.2	8.5
Plastics	—	10.2	—
Vegetable Oil Extraction	—	1.3	4.6
Adhesives	0.7	6.5	—
Insecticides	6.1	1.7	0.4
Unidentified Uses	0.0	0.0	0.0
Total	100	100	100

10.0 SOLVENT CONTENT OF CONSUMER PRODUCTS

The results of the survey of solvent content in consumer products are summarized in Table 12. The table lists consumer product categories and the corresponding annual sales volumes.[16] An indication of the scope of the study may be obtained from the information on the number of brands surveyed and pounds of the product displayed on the shelves in the surveyed supermarkets. As explained in the Methodology section, the weight of products consumed annually in each category was not available and had to be derived from the average price. The average product price obtained by inspection of products displayed on the shelves in the surveyed supermarkets is also listed in the table with the calculated weight of the production consumed.

A total of 46 different brands appearing in 70 different size packages and covering 15 consumer product categories were surveyed in determination of the average price. A total of 21 brands covering 14 product categories were analyzed in the laboratory for solvent content by the fast approximate method developed especially for this purpose.

Since the method was not sufficiently tested and evaluated and the number of the products tested was quite limited, the results should be taken as an approximation. Further uncertainty stems from the fact that the average price, used in calculation of the consumption by weight, was derived from a survey of a limited number of products and without consideration being given to the geographical variation of prices, and to the seasonal variation of the quantities of products displayed. Nevertheless, the results, placing the total solvent consumption through consumer products in the neighborhood of 300 gg (600 lb x 10^6) annually, are in the same range as the estimate based on the survey of the end uses of the individual solvents.

This consumer product study may be viewed as a potential starting point for a more detailed and comprehensive effort. The results obtained here would be very helpful in determining priorities for such work. The emphasis could be properly placed on those products which appear to have the highest solvent content and which have the largest annual consumption.

TABLE 12

SOLVENT CONTENT OF CONSUMER PRODUCTS

	No. Brands Surveyed / No. of Sizes	Total lbs Displayed	Average Price ($/lb)	Total Domestic Consumption		Total Solvent in Product gg/y* ($lbs \times 10^6$)	No. Brands Analyzed	% Solvent in Product (by wt)
				$\$ \times 10^6$ (a)	gg/y* ($lbs \times 10^6/y$)			
Liquid Cleaners and Cleansers	5/11	330	0.67	324	220 (484)	140 (310)	1	64
Rug Cleaners	1/1	40	1.33	53.5	18 (40)			
Home Dry Cleaners	1/1	3	3	37.3	5.5 (12)	3 (6)	1	48
Window Cleaners	3/10	808	0.60	40.2	30 (67)			
Air Fresheners	3/3	124	1.48	140.3	43 (95)	24 (53)	2	56
Furniture Polishes	7/10	699	1.62	78.2	22 (48)	5 (12)	1	26
Automobile Polishes	2/3	51	2.52	93.1	17 (37)	14 (30)	2	81
Floor Waxes and Polishes	7/11	636	1.09	266	120 (262)	6 (13)	3	5
Insecticides	8/9	147	2.15	60.1	13 (28)	3 (6)	3	22
Insect Repellants	1/1	2	3	10.3	1 (3)	0.5 (1)	1	47
Shoe Polishes	3/4	61	6	198	17 (37)	10 (21)	2	57
Hair Care	2/3	36	3.65	.248	31 (68)	10 (21)	2	31
Nail Polish	1/1	3	28	119	2 (4)	1 (3)	1	65
Nail Polish Remover	1/1	15	2	24	6 (14)	4 (8)	1	60
Deodorant	1/1	56	1.94	238	67 (148)	—	1	—
Winshield Washers							1	82
								31
								82
Total	46/70				610 (1350)	220 (490)	21	

* gg = 10^3 mt = 10^6 kg = 2.2×10^6 lb

(a) data from reference 14

11.0 REFERENCES

1. "Control Techniques for Volatile Organic Emissions From Stationary Sources," Radian Corp., prepared for U.S. EPA, Contract No. 68-02-2680, Tasks 12 and 23, February, 1978.
2. Chemical Marketing Reporter, Chemical Profiles (weekly), Schnell Publishing Company.
3. "Chemical Economic Handbook," Stanford Research Institute, Menlo Park, California.
4. "Sampling and Testing Volatile Solvents for Use in Paint, Varnish, Lacquer and Related Products," ASTM Method D 268-9, Annual Book of ASTM Standards, Part 20, American Society for Testing and Materials, Philadelphia, PA.
5. "Procedure for the Preparation of Emission Inventories for Volatile Organic Compounds: Volume I," U.S. E.P.A., Office of Air Quality Planning and Standards, Research Triangle Park, N.C., December 1977, EPA-450/2-77-028.
6. Morgenstern, P., Shah, M.C., Sherman, F.C.," A Methodology for Estimating VOC Emissions from Industrial Sources," presented at the 71st annual meeting of the American Institute of Chemical Engineers, November, 1978.
7. "Methodologies for Countywide Estimation of Coal, Gas and Organic Solvent Consumption," Abcor, Inc., Walden Research Division, prepared for U.S. EPA under Contract No. 68-02-1410, December, 1975.
8. "Hydrocarbon Pollutant Systems Study, Volume I, Stationary Sources, Effects and Control," MSA Research Corp., prepared for U.S. EPA, National Technical Information Service (NTIS) No. PB-219-073. October, 1972, PIII-66.
9. Kirk-Othmer Encylcolpedia of Chemical Technology, 2nd edition, Interscience, John Wiley & Sons (1969).
10. Personal comunication with Mr. Love, Editor, Chemical Profiles, Chemical Marketing Reporter.
11. "Energy Data Reports," Department of Energy, Energy Information Administration, Washington, D.C.
12. "Instructions for the Preparation of the Monthly Refinery Report," FEA-P320-M-0), Federal Energy Administration, Washington, D.C.
13. "U.S.A. Oil Industry Directory, 1977," 16th edition, The Petroleum Publishing Company, Tulsa, Oklahoma.
14. "Thomas Register of American Manufacturers and Thomas Register Catalog File," 68th edition, Thomas Publishing Co., New York, NY.
15. Personal communication with Mr. James Hickey, Director of Chemicals, Charles H. Kline & Co., Inc., Fairfield, N.J.
16. Supermarketing, September 1978, p. 66. (Monthly publication by Gralla Publications, New York, N.Y.).

END USES OF SOLVENTS CONTAINING VOLATILE ORGANIC COMPOUNDS

PART II

EXEMPTIONS OF SMALL SOURCES OF VOLATILE ORGANIC COMPOUNDS FROM EMISSION CONTROL REQUIREMENTS

FINAL REPORT
BY
NED OSTOJIC

TRC - THE RESEARCH CORPORATION OF NEW ENGLAND
WETHERSFIELD, CONNECTICUT

CONTRACT NO. 68-02-2615
TASK NO. 8

EPA PROJECT OFFICER
MR. JOSEPH A. McSORLEY
INDUSTRIAL ENVIRONMENTAL RESEARCH LABORATORY/RTP

EPA TASK MANAGER
MR. EDWIN J. VINCENT
OFFICE OF AIR QUALITY PLANNING AND STANDARDS

MAY, 1979
U.S. ENVIRONMENTAL PROTECTION AGENCY
RESEARCH TRIANGLE PARK, NORTH CAROLINA

1.0 SUMMARY

Control programs for volatile organic compounds (VOC) are presently being developed by the EPA's Office of Air Quality Planning and Standards. Industries and processes which represent major sources of VOC emissions were identified as part of this effort.

Many of these industry categories contain production establishments of widely different sizes. Sizes of VOC sources vary correspondingly. Control of VOC emissions from smaller sources is frequently less cost effective. Factors such as capital availability, capability to undertake research and development effort, etc., frequently favor larger establishments.

Small sources within most industries outnumber the large ones. Therefore control of small sources requires a disproportionate enforcement effort with regard to the actual amount of emission controlled.

The overall cost to benefit ratio of a regulation could be optimized with less stringent control requirements for small sources. One way of achieving this would be by exempting small sources from all control requirements. Alternatively, small sources could be exempt from some control requirements imposed on larger sources.

The objective of this study was to formulate criteria which could be applied in development of small source control strategies. The criteria summarized below, should prove valuable in various stages of the regulatory process. They can be applied in the initial industry screening studies for developing important background correlations between process scale and the feasibility of the emission control for individual industries. The criteria should also be of help in later stages, during development of actual regulations when region specific factors must be considered.

1.1 Summary of Small Source Exemption Criteria

The small source exemption criteria are grouped into four categories, depending on whether they are primarily related to emission control economics, process technology, distribution of sources by size or other factors.

1.1.1 Economics of Small Source Emission Control

A. Cost effectiveness of VOC control is expressed as the capital and/or annual operating cost per ton of VOC controlled, as a function of source size. It allows control cost comparisons for different types of sources and for various emission control alternatives.

B. Differential cost effectiveness measures the rate at which cost effectiveness deteriorates for small sources. Mathematically it represents a derivative of the cost effectiveness criterion as defined in A.

C. Unit cost represents the capital and/or operating cost of VOC control per unit size of control equipment, as a function of source size.

D. Differential unit cost measures the rate at which the unit cost increases for smaller sources. In the mathematical sense, it represents a derivative of the unit cost as defined in C.

E. Economic impact of the VOC control regulation on the industry and specifically on small sources can be measured using the following ratios:

1. Capital expenditures required for control/company's total assets, as a function of company size (company size can be measured e.g. by volume of sales, number of employees, etc.).
2. Capital expenditures required for control/company's productive assets, as a function of company size.
3. Annual cost of control/income before taxes, as function of company size.

F. Additional economic factors affecting the company's control program and having a particular impact on smaller establishments are:

1. Availability of funds (interest rate).
2. Feasibility of solvent and/or heat recovery as affected by prices of solvents and fuel.

3. Cost of acquiring new, low - solvent or no - solvent technologies may be higher for small sources. Smaller establishments may have fewer production lines and may be less able to absorb losses of material and production time as well as the associated potential loss of business or customers. They are also less likely to have the required highly qualified personnel.

1.1.2 Technological Process Characteristics

Process Characteristics

A. Distribution of process batch size as related to process scale (e.g. duration of shortest, average, longest batch). Short batches imply frequent discontinuities in the emissions with the associated changes in concentration which tend to reduce the efficiency of the control equipment.

B. Number of different products, requiring different solvent mixtures, as related to process scale. Different solvent mixtures reduce the technical feasibility of recovered solvent reuse. They also inhibit the economy of scale in solvent recovery.

C. Batch diversity as a function of process scale (e.g. number of batches requiring different coating formulations). Frequent changes in composition of the emissions unfavorably affects the efficiency of solvent recovery and reuse.

D. Number of functional requirements imposed on the product. Frequently complex functional requirements, which the product must satisfy, make substitution by low/no solvent technologies difficult or altogether impossible. These technologies may thus be beyond the reach of small establishments which often cannot afford the required research and development effort.

E. Dependence of operating and maintenance practices on process scale. Small sources could be exempt from more costly control alternatives by means of prescribed operation and maintenance standards. For instance, metal degreasing for maintenance purposes often represents a small scale intermittent operation. This operation can be effectively controlled by observing proper operating procedures such as preventing the tank cover from being open unnecessarily.

Emission Characteristics

Emission characteristics are strongly affected by the process characteristics presented above. Complexity of the emissions, which can be related to source size, affects technical feasibility of emission control. It depends on:

A. Number of solvents used;
B. Frequency of change in solvent composition; and,
C. Variability of solvent concentration.

Energy Considerations

Criteria related to energy consumption in emission control are similar to the ones related to the economics of control, which are presented under 1.1.1. Several examples of energy related criteria are listed below:

A. Energy consumption for emission control as related to source size (e.g. BTU/hr/SCFM, or BTU/hr/lbs solvent emitted/hr, etc.).

B. Unit energy consumption - energy consumption for emission control per unit equipment size, as related to source size (e.g. BTU/hr/SCFM/lbs solvent emitted/hr).

C. Differential unit energy consumption - mathematically, a derivative of the unit energy consumption.

1.1.3 Criteria Related To Source Distribution

A. Contribution of small sources to total regional VOC emissions for a given industry. Significant contribution of small sources to total regional VOC emissions may require reduction in their emissions in order that the overall regional VOC emission reduction objectives can be realized. Thus a complete exemption of small sources from control requirements may be precluded.

B. Distribution of sources by size. Knowledge of source size distribution allows optimization of the regional control strategy. A large number of sources may sometimes be included in or excluded from the emission control exemption by a relatively small change in the definition of an exempted small source.

C. Enforcement effectiveness rato. A quantitative or semi-quantitative estimate of the required enforcement effort as a function of the number and size of sources to be enforced is needed. VOC control strategy can then be developed to achieve an optimum emission reduction per unit cost of the enforcement effort (which can be expressed e.g. in man-hours/source).

1.1.4 Other Considerations

A. Discouragement of circumvention of regulations. Reduced control requirements for small sources should not encourage tendencies to circumvent the regulations by "slipping" into the exempt bracket.

B. Health effects. Toxicity of emissions may preclude exemptions from emission control regulations.

C. Certified testing. Emissions from certain standardized sources may be tested by certified laboratories. This could eliminate a need for the field testing of VOC emissions and thereby reduce the cost related to permit procedures and enforcement for small sources.

2.0 REGULATORY ASPECTS OF SMALL SOURCE EXEMPTIONS

Two basic types of exemptions can be used in a regulatory definition of a small source: absolute and partial exemption. A source emitting volatile organic compounds (VOC) at less than a given minimum rate could be exempt from all emission control requirements. This would constitute an "absolute" exemption. A "partial" exemption would still require some degree of emission control from small sources although less than from the larger ones. The following types of regulations are either directly or indirectly concerned with source size and thus constitute cases of complete or partial exemptions:

1. No controls required below certain emission rate;
2. No controls, or less controls, required for certain types of equipment within a given process;
3. No control, or less controls, required below certain process rate; and,
4. Specified type of control equipment and/or operating and maintenance practices required for sources above given size.

2.1 Absolute Exemptions

Assisting the states in revision of the States Implementation Plans, EPA developed model regulations which provide examples of "absolute" exemptions of small sources. One such example is presented below:[1]

> "...These regulations (referring to control of VOC emissions) will not apply to sources whose emissions of volatile organic compounds are not more than 6.8 kilograms (15 pounds) in any 1 day, nor more than 1.4 kilograms (3 pounds) in any 1 hour, provided the emission rates are determined and certified before March 1, 1979 in a manner approved by the Director."

There are facilities, such as analytical laboratories, which intermittently emit small amounts of VOC. Such facilities may be specifically exempt from emission control requirements. An example of such an exemption is also offered in the above mentioned model regulation:[1]

"...These (VOC) regulations will not apply to sources used exclusively for chemical or physical analysis or determination of product quality and commerical acceptance provided;

(i) operation of the source is not an integral part of the production process; and,

(ii) the emissions from the source do not exceed 363 kilograms (800 pounds) in any calendar month; and,

(iii) the exemption is approved in writing by the Director."

2.2 Partial Exemption of Small Sources

Advantages of the partial exemption of small sources have been recognized in EPA's model regulations. Model regulation for the metal cleaning industry provides a good example of partial exemption of small sources.[1]

This regulation has different control requirements for various metal cleaning processes. The differences are related to technical process characteristics, operating and maintenance practices and control economics. Many of these factors are related to source size. Thus, stringency of the recommended control requirements decreases in order: conveyorized degreasing, vapor degreasing and cold cleaning, reflecting decreasing source size. Even within one metal cleaning process category, cold cleaning, less control is required for solvents with lower vapor pressure. Lower vapor pressure results in lower evaporation rate. Therefore, the regulation distinguishing between lower and higher vapor pressure in this case, in fact, distinguishes between a smaller and a larger source.

The model metal cleaning regulation is listed below in its entirety. The sections (d), (e), and (f) illustrate the increasing stringency of control requirements with increasing source size in the following order: cold cleaning, vapor degreasing and conveyorized cleaning. The regulation also makes other distinctions of source sizes as illustrated by the underlined sections in the text below.

"Solvent Metal Cleaning.

(a) For the purpose of this section, the following definitions apply:

(1) "Cold cleaning" means the batch process of cleaning and removing soils from metal surfaces by spraying, brushing, flushing or immersion while maintaining the solvent below its boiling point. Wipe cleaning is not included in this definition.

(2) "Conveyorized degreasing" means the continuous process of cleaning and removing soils from metal surfaces by operating with either cold or vaporized solvents.

(3) "Freeboard height" means the distance from the top of the vapor zone to the top of the degreaser tank.

(4) "Freeboard ratio" means the freeboard height divided by the width of the degreaser.

(5) "Open top vapor degreasing" means the batch process of cleaning and removing soils from metal surfaces by condensing hot solvent vapor on the colder metal parts.

(6) "Solvent metal cleaning" means the process of cleaning soils from metal surfaces by cold cleaning or open top vapor degreasing or conveyorized degreasing.

(b) Nothwithstanding § XX.9102, after December 31, 1978 this section will apply, in accordance with § XX.9300, to cold cleaning, open top vapor degreasing and conveyorized degreased operations.

(c) The provisions of this section shall apply with the following exceptions;

(1) open top vapor degreasers with an open area smaller than 1 square meter (10.8 square feet) shall be exempt from paragraphs (e) (3) (ii) and (e) (3) (iv) of this section,

(2) conveyorized degreasers with an air/vapor interface smaller than 2.0 square meters (21.6 square feet) shall be exempt from paragraph (f) (2) of this section,

(3) sources exempted under § XX,9102(b).

(d) Except as provided under paragraph (c) of this section, the owner or operator of a cold cleaning facility shall;

(1) equip the cleaner with a cover and the cover shall be so designed that it can be easily operated with one hand; if,

(i) the solvent volatility is greater than 2 kilo Pascals (15 millimeters of mercury or 0.3 pounds per square inch) measured at 38°C (100°F), except that the drainage facility may be external for applications where an internal type cannot fit into the cleaning system; and,

(ii) the solvent is agitated; or,

(iii) the solvent is heated; and,

(2) equip the cleaner with a facility for draining cleaned parts and the drainage facility shall be constructed internally so that parts are enclosed under the cover while draining if the solvent volatility is greater than 4.3 kilo Pascals (32 millimeters of mercury or 0.6 pounds per square inch) measured at 38°C (100°F), except that the drainage facility may be external for applications where an internal type cannot fit into the cleaning system; and,

(3) install one of the following control devices if the solvent volatility is greater than 4.3 kilo Pascals (33 millimeters of mercury or 0.6 pounds per square inch) measured at 38°C (100°F), or the solvent is heated above 50°C (120°F);

(i) freeboard that gives a freeboard ratio greater than or equal to 0.7; or,

(ii) water cover (solvent must be insoluble in and heavier than water); or,

(iii) other systems of equivalent control, such as refrigerated chiller or carbon adsorption, approved by the Director; and,

(4) provide a permanent, conspicuous lable, summarizing the operating rquirements; and,

(5) store waste solvent only in covered containers and not dispose of waste solvent or transfer it to another party, such that greater than 20 percent of the waste solvent (by weight) can evaporate into the atmosphere; and,

(6) close the cover whenever parts are not being handled in the cleaner; and,

(7) drain the cleaned parts for at least 15 seconds or until dripping ceases; and,

(8) if used, supply a solvent spray that is a solid fluid stream (not a fine, atomized or shower type spray) at a pressure which does not cause excessive splashing.

(e) Except as provided under paragraph (c) of this section, the owner or operator of an open top vapor degreaser shall;

(1) equip the vapor degreaser with a cover that can be opened and closed easily without disturbing the vapor zone; and,

(2) provide the following safety switches;

(i) a condenser flow switch and thermostat which shuts off the pump heat if the condenser coolant is either not circulating or too warm; and,

(ii) a spray safety switch which shuts off the spray pump if the vapor level drops more than 10 centimeters (4 inches); and,

(3) install one of the following control devices;

(i) powered cover, if the freeboard ratio is greater than or equal to 0.75, and if the degreaser opening is greater than 1 square meter (10 square feet); or,

(ii) refrigerate chiller; or,

(iii) enclosed design (cover or door open only when the dry part is actually entering or exiting the degreaser); or,

(iv) carbon adsorption system, with ventilation greater than or equal to 15 cubic meters per minute square meter (50 cubic feet per minute per square foot) of air/vapor area (when cover is open), and exhausting less than 25 parts per million of solvent averaged over one complete adsorption cycle; or,

(v) a control system, demonstrated to have control efficiency equivalent to or greater than any of the above, and approved by the Director; and,

(4) keep the cover closed at all times except when processing workloads through the degreaser; and,

(5) minimize solvent carryout by;

(i) racking parts to allow complete drainage; and,

(ii) moving parts in and out of the degreaser at less than 3.3 meters per second (11 feet per minute); and,

(iii) holding the parts in the vapor zone at least 30 seconds or until condensation ceases; and,

(iv) tipping out any pools of solvent on the cleaned parts before removal from the vapor zone; and,

(v) allowing parts to dry within the degreaser for at least 15 seconds or until visually dry; and,

(6) not degrease porous or absorbent materials, such as cloth, leather, wood or rope; and,

(7) not occupy more than half of the degreaser's open top area with a workload; and,

(8) not load the degreaser to the point where the vapor level would drop more than 10 centimeters (4 inches) when the workload is removed from the vapor zone; and,

(9) always spray below the vapor level; and,

(10) repair solvent leaks immediately, or shutdown the degreaser; and,

(11) store waste solvent only in covered containers and not dispose of waste solvent or transfer it to another party, such that greater than 20 percent of the waste solvent (by weight) can evaporate into the atmosphere; and,

(12) not operate the cleaner so as to follow water to be visually detectable in solvent exiting the water separator; and,

(13) not use ventilation fans near the degreaser opening, nor provide exhaust ventilation exceeding 20 cubic meters per minute per square meter (65 cubic feet per minute per square foot) of degreasing open area, unless necessary to meet OSHA requirements; and,

(14) provide a permanent, conspicuous label, summarizing the operating procedures of paragraphs (e) (4) through (e) (12) of this section.

(f) Except as provided under paragraph (c) of this section, the owner or operator of a conveyorized degreaser shall;

(1) not use work place fans near the degreaser opening, nor provide exhaust ventilation exceeding 20 cubic meters per minute per square meter (65 cubic feet per minute per square foot) of degreaser opening, unless necessary to meet OSHA requirements; and,

(2) install one of the following control devices;

(i) refrigerated chiller; or,

(ii) carbon adsorption system, with ventilation greater than or equal to 15 cubic meters per minute per square meter (50 cubic feet per minute per square foot) or air/vapor area (when downtime covers are open), and exhausting less than 25 parts per million of solvent by volume averaged over a complete adsorption cycle; or,

(iii) a system, demonstrated to have a control efficiency equivalent to or greater than paragraph (f) (2) (i) or (f) (2) (ii) of this section, and approved by the Director; and,

(3) equip the cleaner with equipment, such as drying tunnel or rotating (tumbling) basket, sufficient to prevent cleaned parts from carrying out solvent liquid or vapor; and,

(4) provide the following safety switches;

  (i) a condenser flow switch and thermostate which shut off the pump heat if the condenser coolant is either not circulating or too warm; and,

  (ii) a spray safety switch which shuts off the spray pump or the conveyor if the vapor level drops more than 10 centimeters (4 inches); and,

  (iii) a vapor level control thermostat which shuts off the pump heat when the vapor level rises too high; and,

(5) minimize openings during operation so that entrances and exits will silhouette workloads with an average clearance between the parts and the edge of the degreaser opening of less than 10 centimeters (4 inches) or less than 10 percent of the width of the opening; and,

(6) provide downtime covers for closing off the entrance and exit during shutdown hours; and,

(7) minimize carryout emissions by;

  (i) racking parts for best drainage; and,

  (ii) maintaining the vertical conveyor speed at less than 3.3 meters per minute (11 feet per minute); and,

(8) store waste solvent only in covered containers and not dispose of waste solvent or transfer it to another party, such that greater than 20 percent of the waste solvent (by weight) can evaporate into the atmosphere; and,

(9) repair solvent leaks immediately, or shut down the degreaser; and,

(10) not operate the cleaner so as to allow water to be visually detectable in solvent exiting the water separator; and,

(11) place downtime covers over entrances and exits of conveyorized degreasers immediately after the conveyors and exhausts are shut down and not remove them until just before start-up."

3.0 ECONOMIC ASPECTS OF SMALL SOURCE CONTROL

Two major types of controls exist for industrial volatile organic emissions from point sources: process modification and "add-on" controls. The purpose of process modification is to reduce the amount of volatile organic materials released from the process. The add-on control devices serve to destroy or remove volatile organic compounds prior to their emission into the atmosphere.

3.1 Process Modification

Many processes can be modified to reduce the usage or generation of volatile organic compounds. Examples of such process modifications in surface coating include:

1. Change of solvent in a coating formulation from organic solvent to water or to a mixture of water and organic solvents, which results in net decrease in the use of organic solvent;
2. Increase in solid content of the coating to be applied;
3. Reduction in coating thickness;
4. Use of technologies which do not require any solvents at all;

Economic aspects of process modification are very much different from one process to another. New low/no solvent processes may require more expensive equipment, or more expensive operating and maintenance practices. An example is offered by the hot melt coating technique used in preparation of pressure sensitive adhesives. The capital expense of hot melt coating equipment is a problem for paper coaters that have already invested heavily in conventional solvent coating equipment.[2]

In many cases, the major problem related to process change is the lack of readily available technological alternatives. For example, low solvent coating systems are not available for all paper coating applications.[2] Of special importance for small sources are those control techniques based on process change, for which the technological know-how has been developed only by larger companies. Thus, water borne emulsions, which can be applied less expensively than solvent - born rubber based adhesives, are already in use for pressure sensitive adhesives. Water borne adhesives have the advantage that they can be applied with conventional coating equipment. However, water borne adhesives cause paper substrate to curl and wrinkle. While some companies have overcome this problem many smaller companies have not.[2]

Small paper coaters will incur higher relative costs in conversion to low/no solvent coatings technologies because of their limited research and development capability when compared to larger establishments.

3.2 "Add-on" Control Equipment

It is generally well known that the cost of control of volatile organic emissions is relatively higher for smaller sources. This is illustrated in Figures 1 to 4.[3] The figures show capital cost and annual cost of controlling volatile organic emissions as a function of the control equipment size (expressed in terms of gas flow rate) for the two most common control techniques: adsorption and incineration. The cost is affected by many technical and economic factors. The technical factors include:

-presence or absence of particulate in the emissions;

-concentration and distribution of particulate if particulate is present;

-concentration of the emitted solvent as a function of time. For example, an end of a batch in surface coating is accompanied with an abrupt reduction of solvent concentration. The new batch may have a significantly different solvent concentration and composition;

-properties of the emitted solvents such as their solubility in water and change of those properties from batch to batch; and,

-control efficiency required (this in turn being a function of other factors such as toxicity, photochemical reactivity etc.).

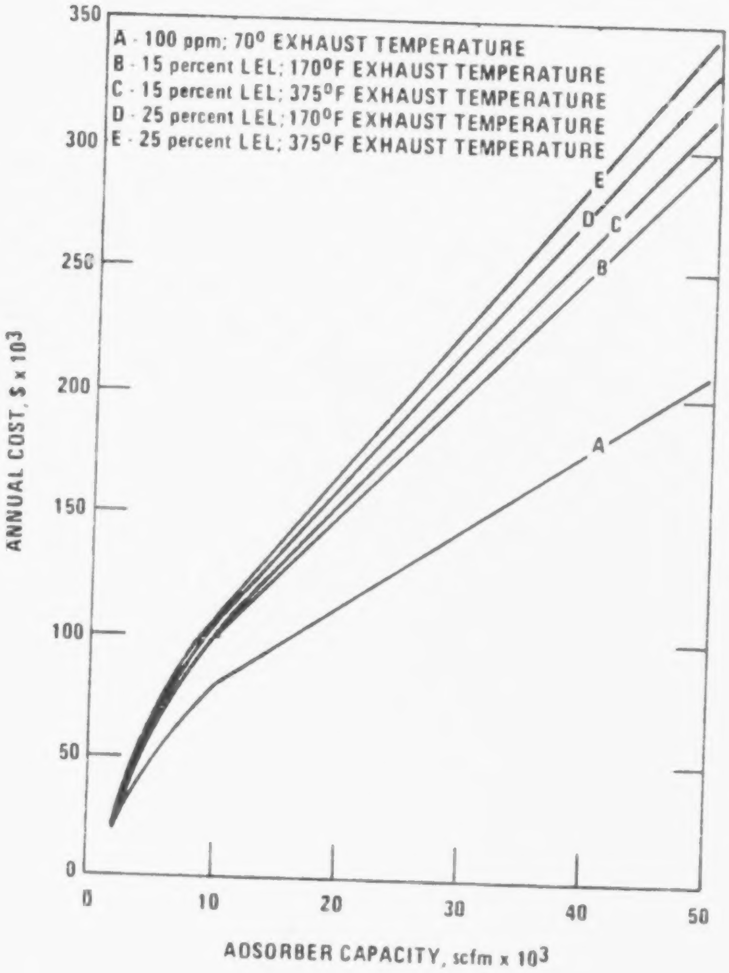


Figure 1: Annual cost of carbon adsorption systems (no credit given for recovered solvents).(3)

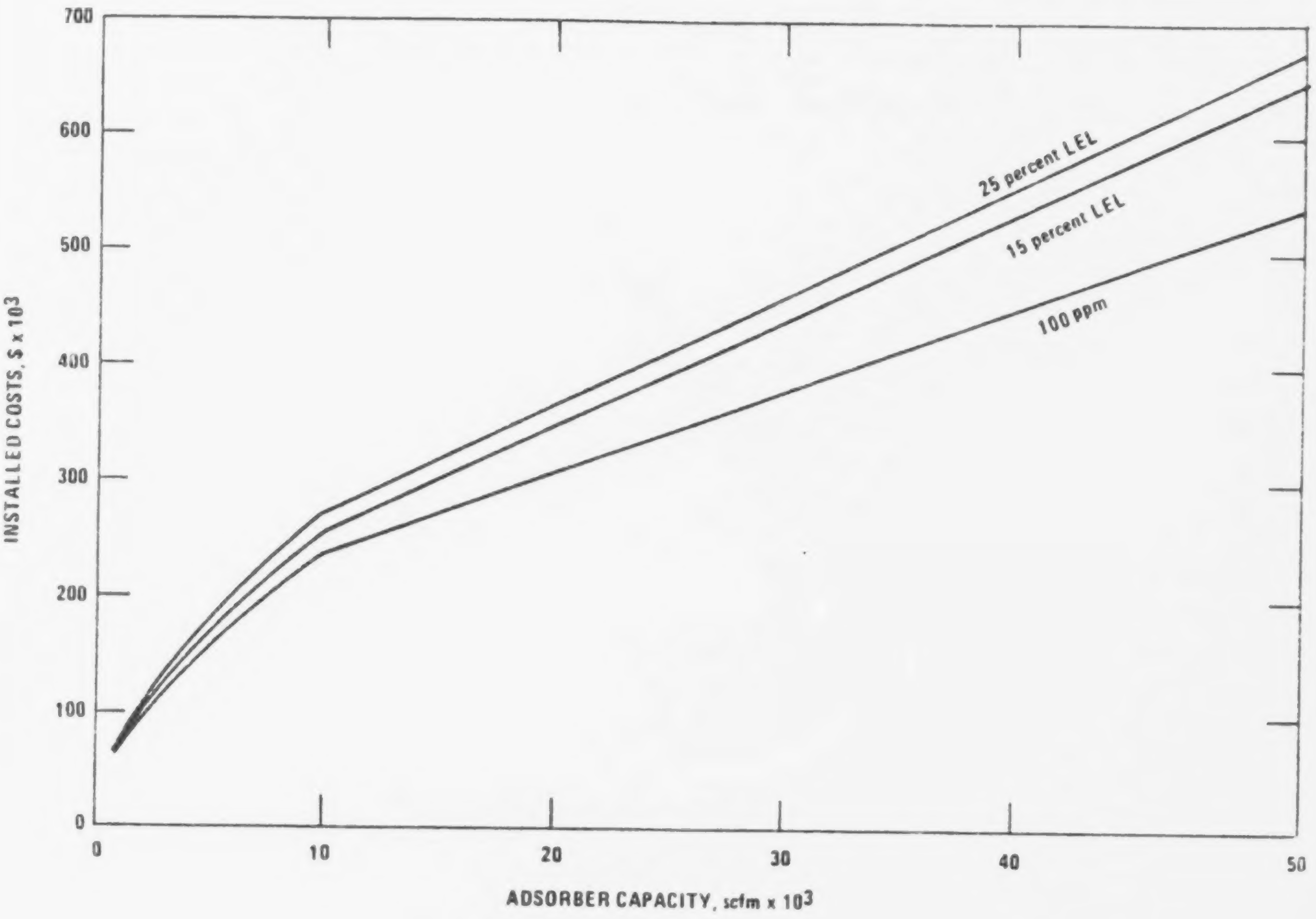


Figure 2: Estimated installed adsorption system cost.(3)

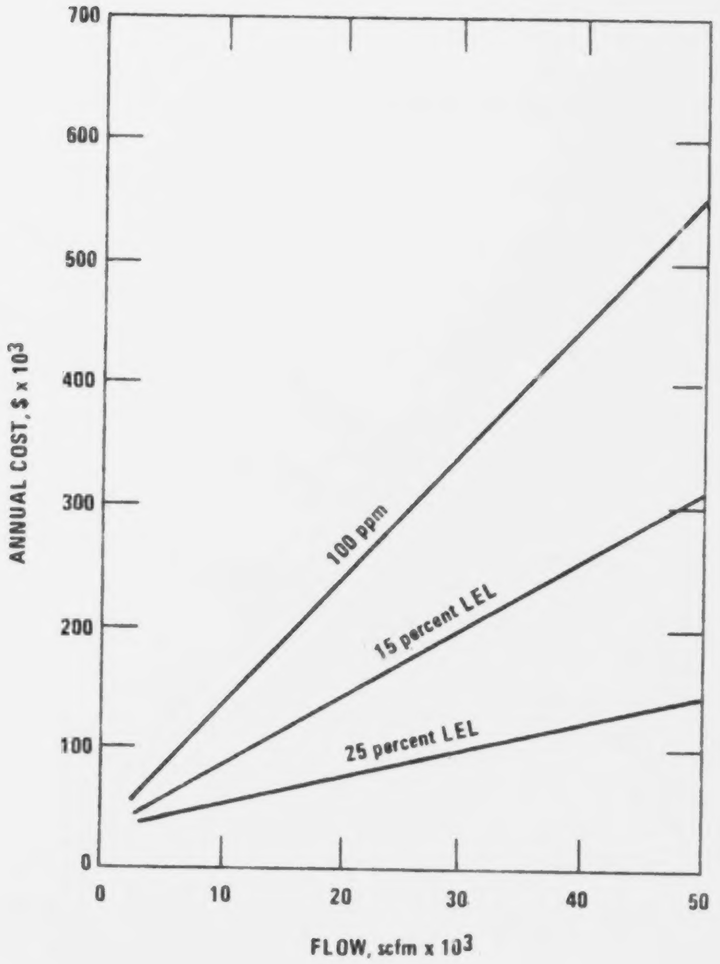


Figure 3: Annual cost of direct flame incinerators with primary heat recovery, process temperature = 70°F (3).

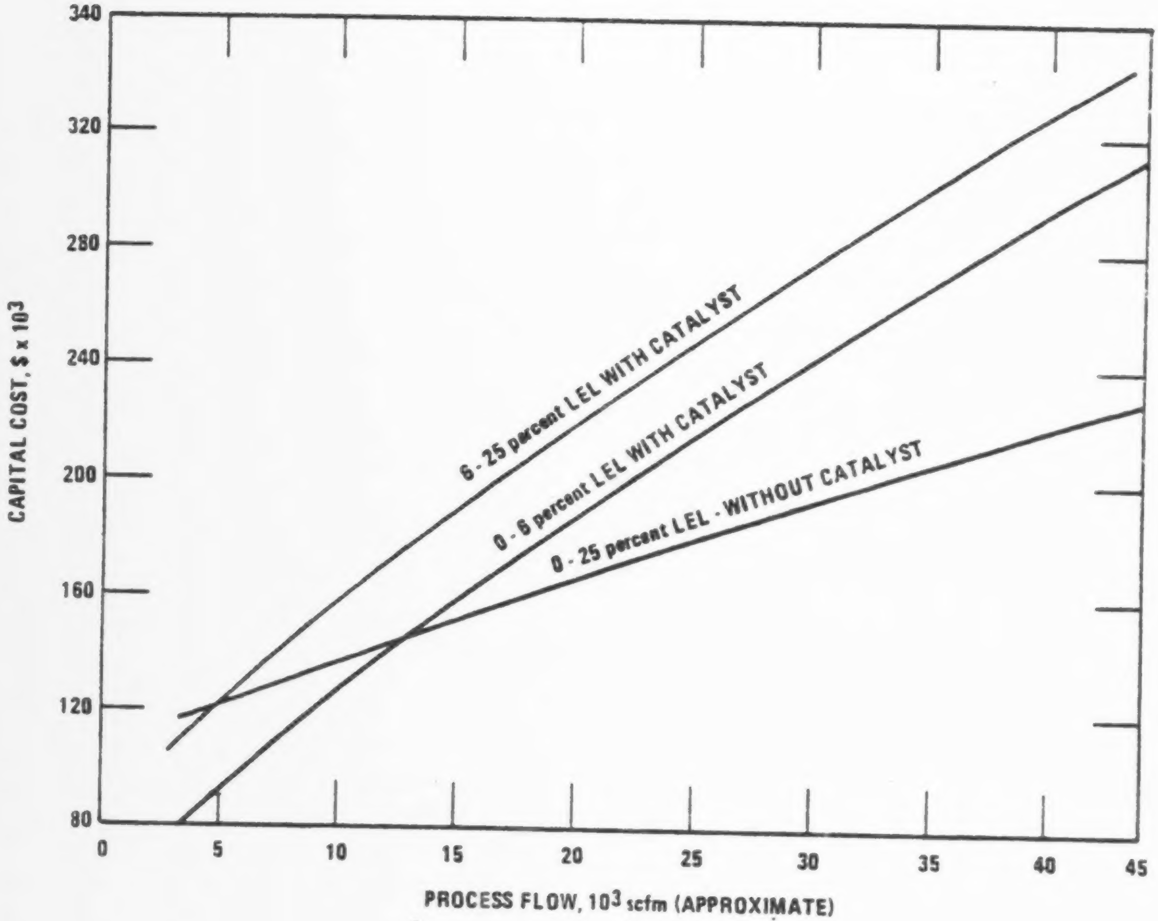


Figure 4: Capital cost for direct flame and catalytic afterburners with primary heat recovery (70 - 300°F process gas inlet). (3)

Presence of particulate in the emissions may require installation of a separate control stage for removal of particulate prior to control of the solvents. Alternatively, if incineration is applied, there may be no need for removal of particulate in a separate stage, but its presence will affect equipment design. Typically, longer residence time will be needed, often resulting in a significant increase in control cost.

Concentration of the solvent affects the control cost in many ways. Thus, at low solvent concentrations, saturation of the carbon bed is reached with less solvent adsorbed than at higher concentrations. This requires more frequent carbon regeneration and thus increases the cost of operation per unit amount of solvent adsorbed. In incineration, the lower heat value of dilute solvent vapors will require a correspondingly higher consumption of costly incineration fuel.

The solubility of the solvent in water plays a role in selecting the proper control technique; for instance, it may interfere with solvent recovery. Water soluble solvents cannot be separated from the water layer by simple, inexpensive decantation if steam stripping is used for carbon bed regeneration. Therefore, more expensive ways of stripping may have to be applied. In any case, solubility of solvent in water may create a related water pollution problem.

The economic factors affecting small sources of solvent emissions include:

-reuse value of the recovered solvent

-solvent cost

-value of solvent as fuel

The major advantage of simple solvent mixtures is that they are very suitable for solvent recovery. When complex solvent mixtures are used, the composition of the recovered solvent is often quite different from the composition of the solvent as used in the process.

A refining process may have to be used if solvent reuse in the original process is desired. Such refining process is easier and more economical for simpler mixtures.

Solvent heat content reduces fuel consumption in incineration. Certain solvents would, if burned, cause serious pollution problems, such as generation of oxygenated chlorine compounds. A separate control stage may be required for these combustion products.

Finally, solvent recovery and reuse can be expected to be more difficult to implement for small sources. Purification of the recovered solvent, often required before reuse, may not be technologically feasible for small sources. Cost of shipment and sales of small quantities of recovered solvent are also higher.

3.3 Criteria for Evaluation of the Economics of Small Source Control

In spite of the complex interrelationship of all the factors which affect the economics of VOC emissions from small sources, many useful generalized correlations exist or can be developed. These correlations can be used as criteria in development of small source control strategies.

Mutual comparisons of the economics of various control alternatives can be conveniently performed by means of a unit cost, which represents the cost per unit equipment size ($/SCFM). This is illustrated for adsorption and incineration in Figures 5 and 6. Figure 5 presents the unit cost of installed control equipment and Figure 6 presents the unit annual operating cost of the control equipment, both as a function of equipment size. The figures clearly show an increase in unit cost for smaller equipment size and the consequently higher cost of control of smaller sources. This increase in unit cost for smaller equipment is more pronounced for adsorption. Because of its simple , relatively easily obtainable and quantitative relationship to the economics of small source control, the unit cost represents a useful criterion for evaluation of small source control alternatives.

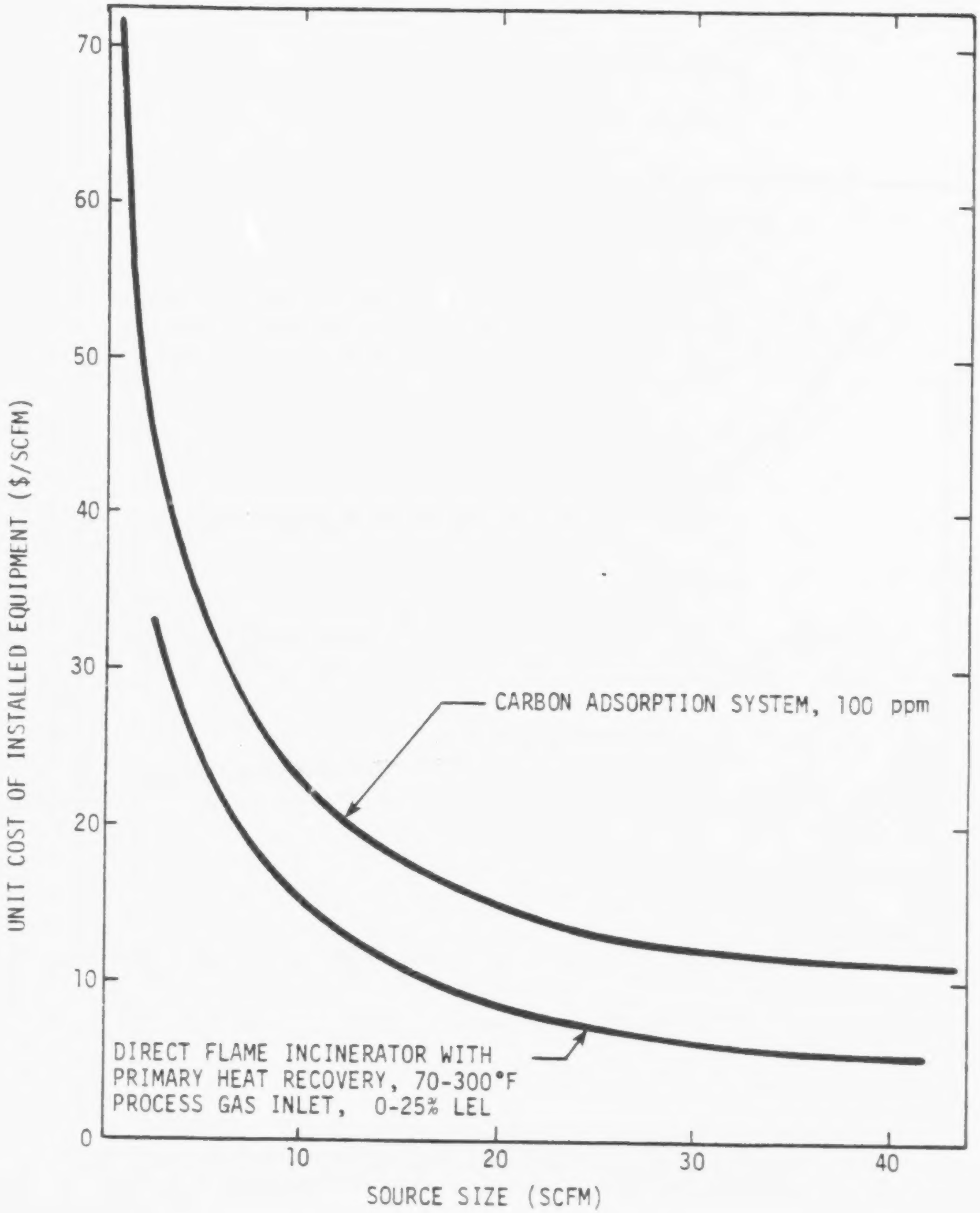


Figure 5: Estimated unit cost for installed adsorber and direct flame incinerator (based on data from reference 3).

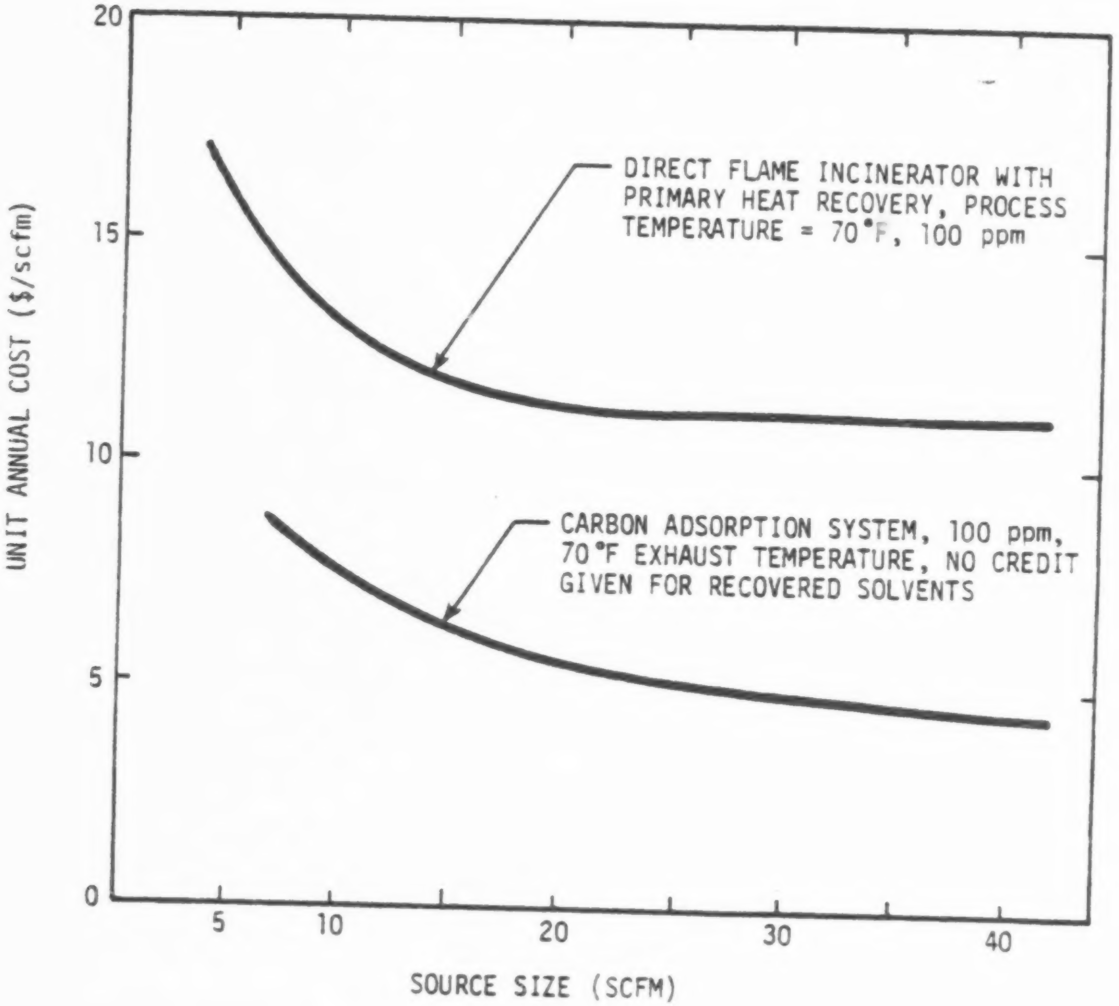


Figure 6: Estimated annual unit cost for absorber and direct flame incinerator (based on data from reference 3).

This criterion could be further refined to more conveniently characterize the increase in unit cost for smaller control equipment. In a mathematical sense the increase in unit cost as a function of equipment size is best characterized by a derivative of a unit cost curve. Use of the absolute values of these alternatives is recommended for the practical advantage of working with positive numbers. It will be referred to here as "differential cost."

Table 1 shows differential unit capital cost for absorption and for incineration, both as a function of equipment size. The values for adsorption and incineration are remarkably close throughout the equipment size range from 5,000 SCFM to 40,000 SCFM. This means that the trend of the unit cost increase for small sources is about equal for adsorption and incineration.

Low differential unit cost values down to 10,000 SCFM indicate that the unit cost of the installed control equipment is quite constant for larger units. Significant increase in differential unit cost values for equipment below 10,000 SCFM illustrates the severity of the economic disadvantage for small sources in VOC emission control.

The differential unit control cost is a convenient quantitative criterion for evaluation of economics of small source control. Its special importance is that it is concerned quite specifically with source size.

Cost effectiveness of emission control can be conveniently expressed as cost per unit amount of VOC controlled. Figure 7 provides an example of such presentation of cost effectiveness in control of VOC emissions from metal cleaning.[4]

Design and operating characteristics of metal cleaning equipment vary considerably as a function of equipment size. Several major equipment types are used: cold cleaners, open top vapor degreasers, and conveyorized degreasers. Equipment size and solvent emissions increase in the order: cold cleaners, open top vapor degreasers, and conveyorized degreasers.

TABLE 1

DIFFERENTIAL UNIT CAPITAL COST FOR ADSORPTION AND INCINERATION[a]

Source Size (SCFM)	Differential Unit Cost[b] ($/SCFM/SCFM)	
	Adsorption[c]	Incineration[d]
1,000	24	
5,000	3.0	2.7
10,000	1.2	1.0
20,000	0.46	0.32
30,000	0.16	0.15

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[a] Based on cost for installed equipment from Reference 3.

[b] Absolute value of the derivatives used.

[c] Carbon adsorption system, 100 ppm.

[d] Direct flame incinerator with primary heat recovery, 70-300°F process gas outlet, 0-25% LEL.

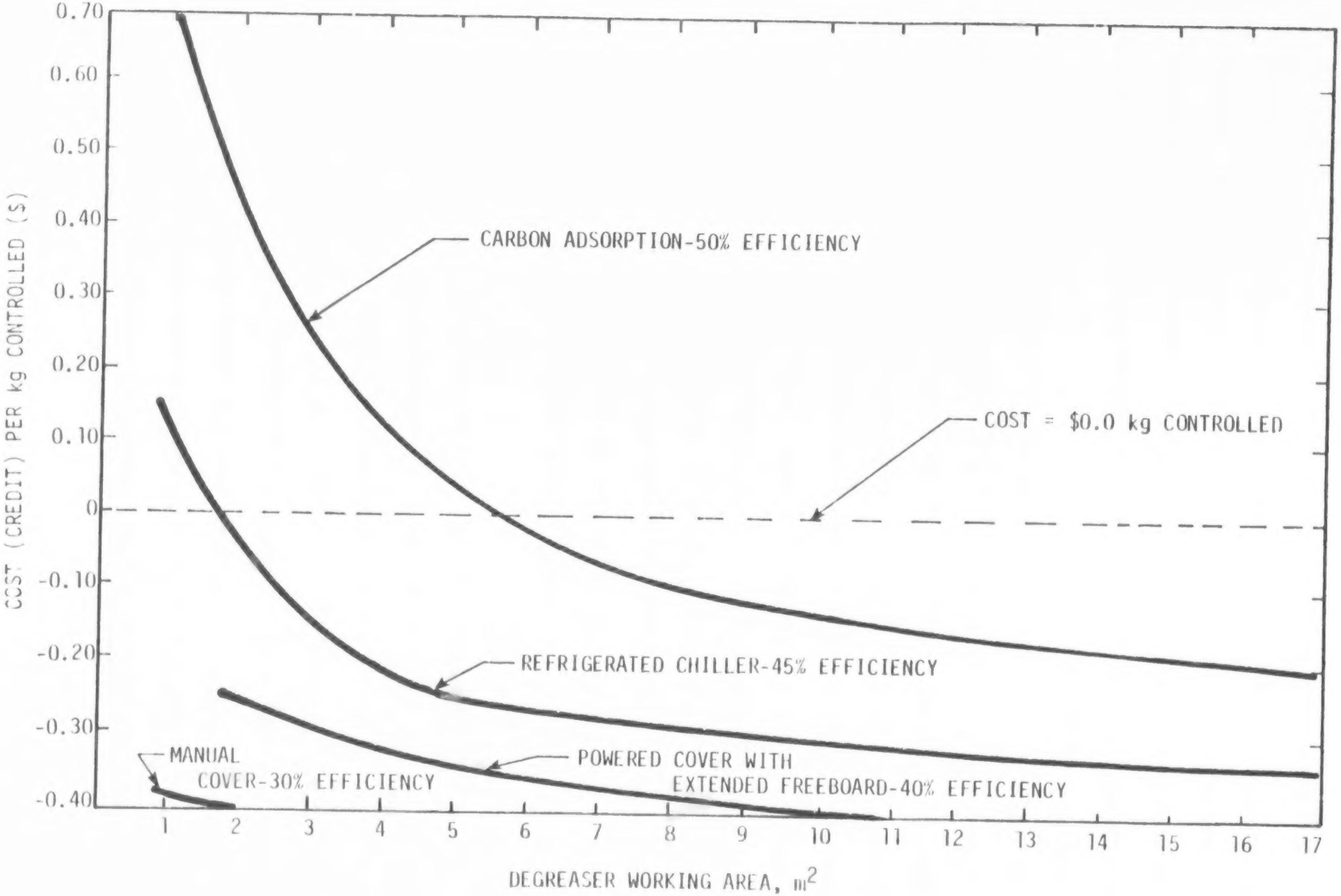

Figure 7: Cost-effectiveness of alternative control options for existing open top vapor degreasers. (4)

Cold cleaners with a working area of 0.5 m^2 and corresponding annual emissions of 0.25 metric tons of solvent belong to the small source category. Small size open top vapor degreasers with an annual emission of 4.75 metric tons (17 lbs/8hr day) could also be considered small sources. Neither the cross-rod nor monorail conveyorized degreasers can be considered to be small sources even when their uncontrolled emissions are reduced with good house cleaning practices.

In addition to the earlier mentioned add-on control methods which all include transport of solvent vapor through a control device, the following two methods are applicable to control solvent emissions from cold cleaners and open top vapor degreasers: raising the freeboard and installation of a tank cover (operated either manually or with mechanical assistance). The general trend of increased cost of add-on control for small sources and relatively low uncontrolled emissions from cold cleaners make these two control methods very attractive. They are also the most cost effective way of controlling emissions from open top vapor degreasers. This is apparent from Figure 7 which shows the cost effectiveness for various control alternatives for these degreasers. Even for the smallest open top vapor degreasers, the cost of installation and operation of the extended freeboard and powered cover can be completely offset by the achievable savings due to lower solvent usage.

Figure 7 provides a very good example of how cost effectiveness analysis can be used in development of control strategies. The powered cover and the extended freeboard provide control efficiency of 40%. The refrigerated chiller does provide 45% control efficiency, but at a considerably higher cost. Thus, the natural choice for control of small sources is either a manually operated cover with 30% efficiency or the combination of a power cover with an extended freeboard. The example in Figure 7 illustrates the usefulness of cost effectiveness as a criterion in evaluation of control alternatives. Cost effectiveness can naturally be applied to both capital cost and annual cost.

As in the earlier examples of economic criteria related to small sources control, the cost effectiveness criterion can be further refined to more specifically characterize source size. Derivatives of the cost effectiveness curves can again provide useful differential cost effectiveness.

Figure 8 and 9 show cost effectiveness of adsorption and incineration as a function of source size.[3] The values of the derivatives of the curves in these figures are presented in Table 2. Absolute values of these derivatives were used to avoid the inconvenience of working with negative numbers. High values for small sources indicate an unfavorable trend in cost effectiveness for these sources. However, the trend is more favorable for incineration than for adsorption. The differential cost effectiveness singles out the effect of source size on cost effectiveness and therefore, represents a very useful criterion specifically suited for the evaluation of small source control alternatives.

The economic impact of the VOC emission control regulations will frequently depend on the size of the establishment owning the source. A disproportionately severe impact on smaller establishments may have a profound effect on the entire industry structure as well as on the economy in general. Several criteria presented below should be helpful in determining the impact of the VOC control regulations on industry in general and on smaller establishments in particular.

The starting point in the evaluation of the impact of the regulation on industry is the analysis of the business background of the industry. This effort is by its nature complementary to the study of the distribution of sources by size. The most essential business background information needed is: total assets, productive assets, income before taxes, yearly increase in sales and profits, all as a function of the size of industrial establishments. Once this information is available, specific criteria based on the following ratios can be established for analysis of the impact of the regulations:

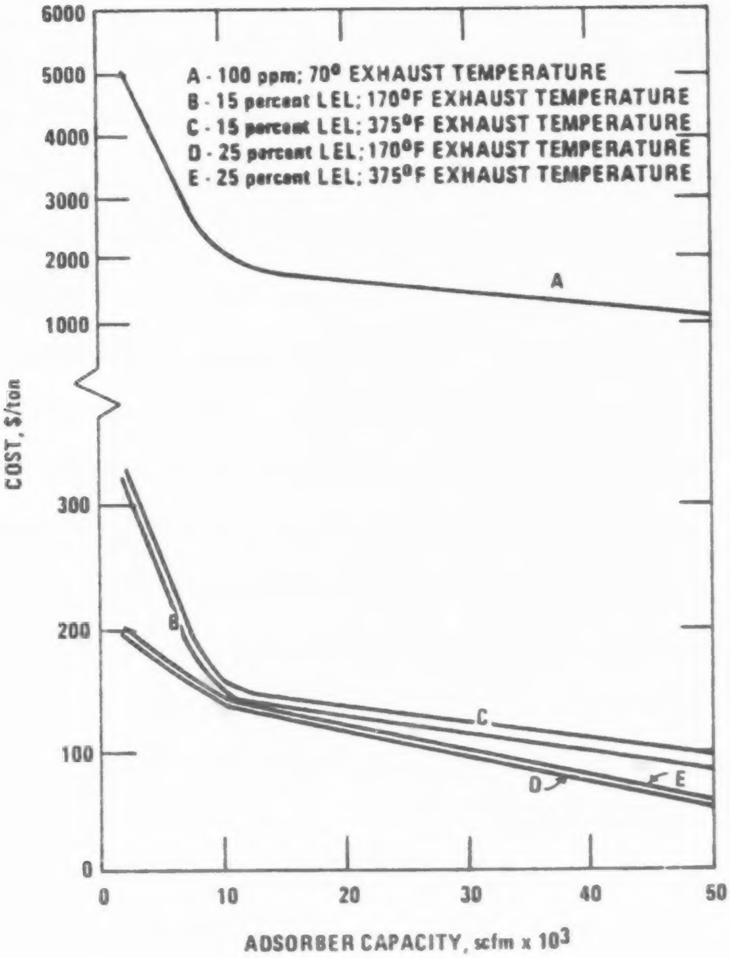

Figure 8: Cost-effectiveness (based on annual cost) of carbon adsorption systems (no credit given for recovered solvents). (3)

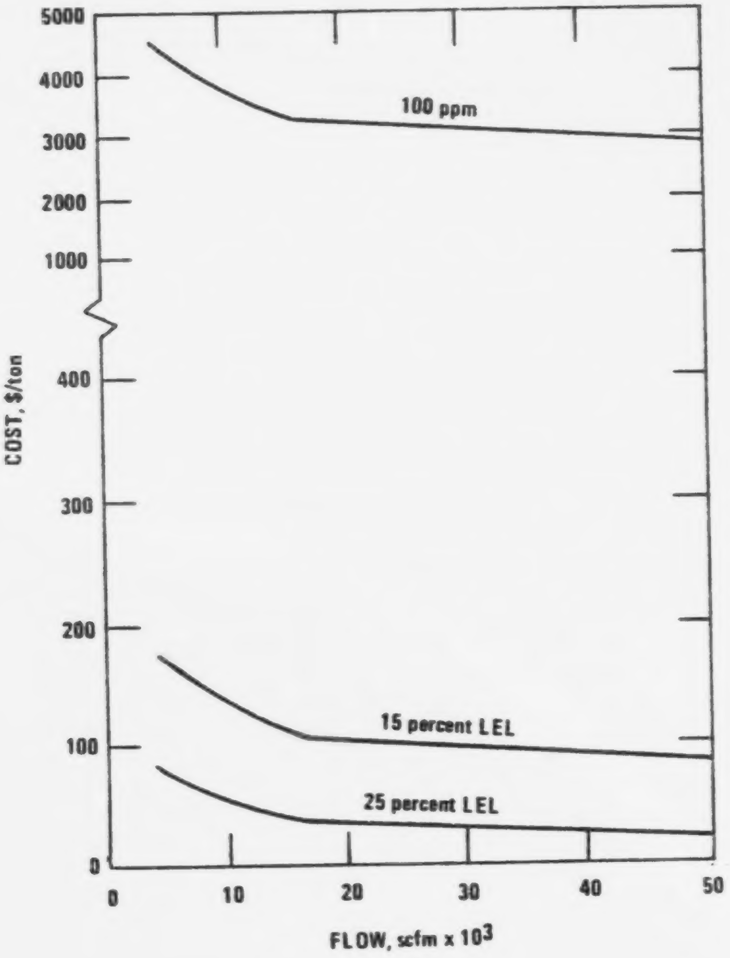

Figure 9: Cost-effectiveness (based on annual cost) of direct flame incinerators (primary heat recovery - process temperature = 70°F). (3)

TABLE 2

DIFFERNTIAL COST EFFECTIVENESS FOR ADSORPTION AND INCINERATION[a]

Source Size (SCFM)	Differential Cost Effectiveness ($/Ton/SCFM)	
	Carbon Adsorption[b]	Incineration[c]
3,000-7,500	400	
10,000		128
20,000-50,000	18	12.5

---

[a] Based on annual cost data from Reference 3.

[b] No credit given for recovered solvents, 100 ppm, 70°F exhaust temperature.

[c] Primary heat recovery, process temperature 70°F, 100 ppm.

-Capital expenditures required for control/company's total assets/company size.

-Capital expenditures required for control/company's productive assets/company size.

-Annual cost control/income before taxes/company size.

Additional economic factors affecting the cost effectiveness of a company's control program and having a particular impact on smaller establishments are the availability of funds (interest rate), and the feasibility of solvent recovery and reuse.

4.0 TECHNOLOGICAL ASPECTS OF SMALL SOURCE CONTROL

Many characteristics of a technological process, such as the raw materials, basic unit operations, products, type of emissions, etc. are often independent of process scale. However, some important technological elements may be affected by process scale. For instance, the design of the equipment may be different at the small and at the large scale end of a process. Operation and maintenance practices are also likely to be affected by process scale. Some characteristics of process emissions such as their concentration, composition, etc. will frequently vary as a function of process scale. As a result, technical feasibility of emission control will often be affected by process scale. This is true for both add-on controls and for low/no solvent technologies.

Two sets of criteria for evaluation of the impact of technological factors on feasibility of small source control can be formulated: emission criteria and process criteria.

Emission criteria are primarily related to the complexity of the emissions. Feasibility of reuse of the recovered solvent or heat is very much affected by the complexity of the emissions. The following criteria can be formulated:

- Complexity of emissions as related to process scale (number of solvents used, frequency of change in solvent composition).
- Variability of solvent concentration as related to process scale. Smaller and diverse batches will result in variable emissions and lower efficiency of control equipment.

Some process criteria related to the complexity of the emissions are:

- Distribution of process batch size as related to process scale (e.g. duration of shortest, average, longest batch). Short batches imply frequent discontinuities in the emissions, with the associated changes in concentration which tend to reduce the efficiency of the control equipment.
- Number of different products, requiring different solvent mixtures, as related to process scale. Different solvent mixtures reduce the technical feasibility of recovered solvent reuse. They also inhibit the economy of scale in solvent recovery.

- Batch diversity as a function of process scale (e.g. number of batches requiring different coating formulations). Frequent changes in composition of the emissions unfavorably affects the efficiency of solvent recovery and reuse.

- Number of functional requirements imposed on the product. Frequently complex functional requirements, which the product must satisfy, make substitution by low/no solvent technologies difficult or altogether impossible. These technologies may thus be moved beyond the reach of small establishments.

Energy consumption for emission control is also an important consideration. Many criteria related to energy consumption in emission control as a function of source size can be formulated. Several examples are listed below. These criteria are very similar to the ones related to the economics of control which are presented in Section 3.3.

- Energy consumption for emission control as related to source size (e.g. BTU/hr/SCFM or BTU/hr/lbs solvent emitted/hr etc.).

- Unit energy consumption - energy consumption for emission control per unit equipment size, as related to source size (e.g. BTU/hr/SCFM/lbs solvent emitted/hr).

- Differential unit energy consumption - mathematically a derivative of the unit energy consumption. This criterion emphasizes the effect of source size on unit energy consumption.

5.0 DISTRIBUTION OF EMISSION SOURCES BY SIZE

In developing control programs for the volatile organic compounds (VOC), priorities are given to those industries and processes which emit larger amounts of VOC. The basic technological and economic characteristics of these industries are studied in the initial phases of development of emission control strategies. The analysis of distribution of the emission sources by size is most beneficial in this initial phase. This analysis should show the contribution of small sources to the overall VOC emissions. Thus, in further study proper emphasis can be placed on analyzing the relationship between source size and the technological and economic characteristics of an industry.

Distribution of emission sources by size is closely related to the enforcement aspects. Small sources often outnumber the large ones within an industry. The enforcement effort increases with an increase in the number of the regulated sources. As smaller and smaller sources are regulated, smaller increments in the overall reduction of VOC emissions are achieved. The result is a diminishing return on the effort.

Nationwide statistical data from the Bureau of Census[5] are employed in Figure 10 to illustrate the distribution of solvent emissions by source size for three industries: dry cleaning, metal cleaning and metal furniture painting. The corresponding Standard Industrial Classification Codes (SIC) for these industries, on which this correlation is based are: 7216, 3451 and 2514 respectively. The distribution curves are cumulative. They represent total emissions from all sources smaller than a given size. The vertical cut off lines correspond to the small source definition in the Los Angeles Rule 66.[6] They represent sources emitting 15 lbs/day and 40 lb/day.

EPA data on average emissions per employee in these industries[7] were used to correlate the number of employees per establishment with the corresponding solvent emissions. It can be seen that the dry cleaning industry is characterized by the largest relative

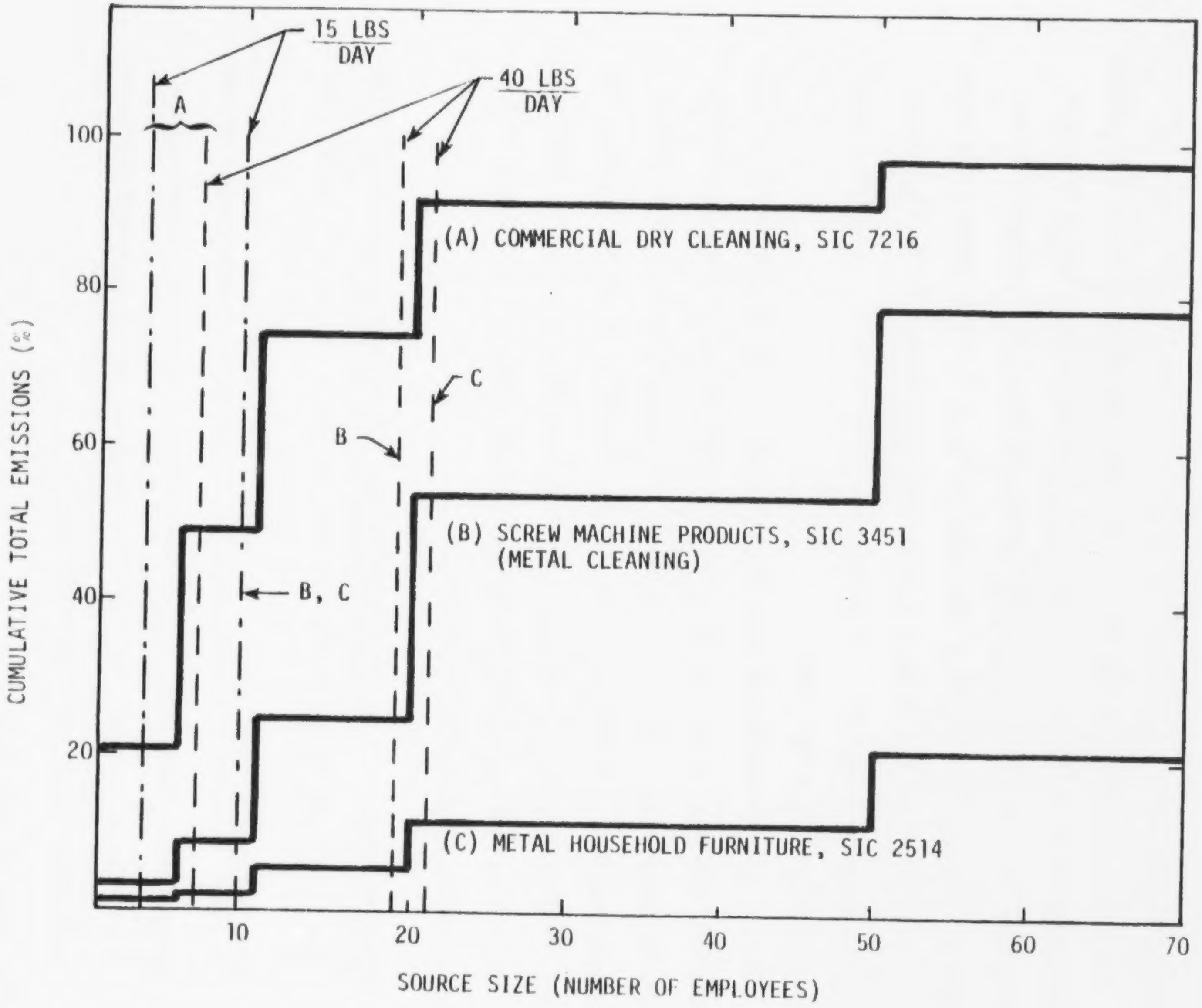

Figure 10: Source distribution by size in dry cleaning, screw machine products and metal household furniture industries.

contribution of small sources to the total solvent emissions. The emission factors typically ignore the size of the establishment. Also in reality, many sources may already be controlled to varying degrees.

Additional restrictions on the validity of the above distribution analysis are imposed by the limitations of the SIC system. The processes, as defined with regard to solvent emissions, do not always clearly correspond to SIC classifications. The latter may be broader or narrower. For instance in illustration in Figure 10, metal cleaning was represented by the Screw Machine Products Industry (SIC Code Number 3451). Many other metal cleaning operations, such as the applications in maintenance, may be fairly independent of the size of the establishment.

The SIC system nevertheless provides a useful tool for regional estimates of VOC emissions.[8] With proper understanding of its limitations, statistical information based on the SIC system could provide valuable insight into the importance of small sources in solvent emissions. The emission factors, which are sufficiently refined to reflect the effect of source size, would be very helpful in developing control strategies. Source size distribution data could then serve as a basis for application of the following criteria related to small source control requirements:

- Contribution of small sources to total regional VOC emissions for a given industry. If the contribution of small sources to total regional VOC emissions is significant, their control may be required in order that the overall regional VOC emission reduction objectives be realized.

- Distribution of sources by size - Knowledge of the source size distribution is required for proper definition of a small source for the purpose of emission control exemption.

- Enforcement effectiveness ratio - A quantitative or semi - quantitative estimate of the required enforcement effort as a function of the number and size of sources to be enforced is needed. VOC control strategy can then be developed to achieve an optimum emission reduction per unit cost of the enforcement effort (which can be expressed e.g. in man-hours/source).

6.0 REFERENCES

1. "Regulatory Guidance for Control of Volatile Organic Compound Emissions from 15 Categories of Stationary Sources," prepared by GCA Corp., Bedford, Massachusetts, for the U.S. Environmental Protection Agency, Chicago, Illinois, April 1978.

2. "Control of Volatile Organic Emissions from Existing Stationary Sources - Volume II: Surface Coating of Cans, Coils, Paper, Fabrics, Automibles and Light Duty Trucks," U.S. Environmental Control Agency, Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina, May 1977, EPA-450/2-77-008.

3. "Control Volatile Organic Emissions from Existing Stationary Sources - Volume I: Control Methods for Surface Coating Operations," U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina, November 1976, EPA-450/2-76-028.

4. "Control of Volatile Organic Emissions from Solvent Metal Cleaning," U.S. Environmental Protection Agency, Office of Air and Waste Management, Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina, Publication No. EPA-450/2-77-022, November 1977.

5. "U.S. Bureau of the Census, County Business Patterns,1976, United States," U.S. Government Printing Office, Washington D.C., 1978.

6. "Controlling Pollution from the Manufacturing and Coating of Metal Products, Solvent Metal Cleaning Air Pollution Control-II," U.S. Environmental Protection Agency, Environmental Research Information Center, Technology Transfer, May 1977.

7. "Supplement No.6 for Compilation of Air Pollution Emmission Factors," 2nd edition, U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, N.C., April 1976.

8. "Methodolgies for Countywide Estimation of Coal, Gas and Organic Solvent Consumption," prepared for the U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina, by Abcor, Inc., Cambridge, Massachusetts, Walden Research Division, December 1975.

END USES OF SOLVENTS CONTAINING VOLATILE ORGANIC COMPOUNDS

PART III

APPLICATION TO EMISSION INVENTORIES

FINAL REPORT
BY
NED OSTOJIC

TRC - THE RESEARCH CORPORATION OF NEW ENGLAND
WETHERSFIELD, CONNECTICUT

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EPA PROJECT OFFICER
MR. JOSEPH A. McSORLEY
INDUSTRIAL ENVIRONMENTAL RESEARCH LABORATORY/RTP

EPA TASK MANAGER
MR. EDWIN J. VINCENT
OFFICE OF AIR QUALITY PLANNING AND STANDARDS

MAY, 1979
U.S. ENVIRONMENTAL PROTECTION AGENCY
RESEARCH TRIANGLE PARK, NORTH CAROLINA

1.0 INTRODUCTION

An effective strategy for control of photochemical oxidants requires knowledge of the sources of their precursors, volatile organic compounds (VOC). This information is obtained by means of an emission inventory. Specifically, an emission inventory provides information about:

- the types of sources present in an area;
- the quantity of pollutant emitted;
- the types of processes and equipment present at each plant;
- the type and number of emission control devices present at each plant.

The primary use of the inventory data is as input to the source/receptor model used by the air pollution control agency to relate emission of precursor pollutants (VOC and NO_x) to the resulting concentrations of photochemical oxidants in the ambient air. Data collection represents the most difficult step in an inventory. Ideally, the best way to gather inventory data is to visit each source and directly determine emissions by source test or material balance. A more common technique used by air pollution control agencies for gathering emission inventory data is the mail survey. A mail survey consists typically of the following steps:

- mailing lists must be prepared;
- questionnaires must be designed;
- data handling procedures must be prepared and organized;
- response receiving systems must be established.

A mailing list tabulates the name, address, and general process category of each facility to be surveyed. Most facilities will fall within some standard industrial classification category designated by a numerical code under the Standard Industrial Classification (SIC) system. The SIC system, in conjunction with solvent end use information, may provide a very useful tool in the planning stages of an emission inventory.

The correlation between solvent usage and the SIC code is especially useful because of a considerable amount of statistical information associated with the SIC system, such as the number of employees in a given industry, etc.[1,2] Thus, preliminary regional solvent emission estimates in a given SIC category could be obtained from regional employment in that category. Preliminary estimates of the emissions can be used to improve the effectiveness of a mail campaign by limiting its scope. This is especially important in the cases when the requirements of a comprehensive mail survey exceed the resources available to the agency. In this regard, procedures have been developed for obtaining emission estimates for small (<50 ton/year) solvent users when the inventorying agency cannot afford to obtain information directly on these sources by questionnaires or plant visits.[3]

Design of a questionnaire is another important task in a mail survey. Questionnaires are typically addressed to the so called "point sources." Point sources are larger sources for which individual records are kept in the inventory file. Conversely, the so called "area sources" are reported collectively. Although the questionnaires are most often directed to the point sources, they may occassionally be used to obtain information on typical area sources as well. For instances, residential combustion is generally treated as an area source. The emissions associated with this area source can be estimated by sending questionnaires to fuel suppliers.

Questionnaires used in mail surveys can be either industry specific or can encompass many source categories. Table 1 provides an example of the information which could be requested in a comprehensive questionnaire.[4] The questionnaire contains ten groups of questions related to solvent use. An example of such questionnaire is included in the Appendix.[4]

Every inventory should cover solvent emissions in the region of interest as completely as possible. Those emissions, not covered by the point source questionnaires,

TABLE 1

TYPICAL INFORMATION REQUESTED IN A SOLVENT USE QUESTIONNAIRE

QUESTION CATEGORY CODE NUMBER	
A	General information about the source such as company name.
B	Address, names of contacts, nature of business, operating schedule, etc.
1	Solvent usage in degreasing operations.
2	Solvent usage in dry cleaning operations.
3	Solvent usage in protective or decorating coatings.
4	Solvent usage in fabric or rubberized coatings.
5	Solvent usage in miscellaneous surface coatings.
6	Operating and design characteristics of ovens.
7	Solvent usage in printing.
8	General solvent usage.
9	Capacity and annual throughput of solvent storage facility.
10	Essential design and operating characteristics of VOC emission control and exhaust system.

plant visits, or other direct means need to be estimated by indirect means. These emissions are released largely from products used in the consumer and commercial sectors. In general, the level of these emissions will correspond to population density and other statistical parameters characterizing the region.

Therefore, the statistical information about a region can be used in estimating emissions from the area sources provided the relationship between this statistical information and solvent emission is known. This relationship can be established on a nationwide basis by means of solvent use data presented in Part I of this report. The most common such relationship associates solvent consumption with population density, resulting in a "per capita" solvent consumption data.

The objectives of Part III of this study are:

- To establish the correlation between the solvent end uses identified in Part I of this report and the SIC categories to facilitate planning of emission inventories.
- To review the scope of information requested in a typical VOC emission questionnaire and identify those solvent emissions which would not be covered by such questionnaires.
- To recommend a way to estimate regional emissions from those end-uses not covered by typical point source inventory procedures.

2.0 CLASSIFICATION OF SOLVENT END USES

In order that the solvent und use information can be effectively utilized in VOC control programs, the identified end uses were classified into industrial and consumer/ commercial sectors. This classification is shown in Table 2.

Several of the end uses in Table 2 appear to overlap although they do not. Some narrowly defined uses appear to be already fully contained in other, more general end use categories. Thus, for example, "Extraction, Vegetable Oil," "Extraction Solvent," "Extraction, Rare Metals" and "Industrial Uses" are listed as separate end uses in the industrial sector in Table 2. Obviously, vegetable oil extraction and rare metals extraction are both extraction processes and wold thus appear already contained in the "Extraction Solvent" category. The "Extraction Solvent" category appears in turn already contained in the more general "Industrial Processes" category.

This apparent overlap results from the method employed in solvent consumption estimates. The available end use information was much more detailed for some solvents than for the others. Solvents for which only less detailed breakdown was available were by necessity classified into more general categories.

It is important to realize that these more general categories, as presented in Table2, do not contain any of the solvents from the more specific categories. Reference to the Tables A1 and A2 in the Appendix of Part I will help resolve any ambiguities. Thus, in the above example of extraction solvents, Table A2 will show that the 11 gg/y solvent consumed in the "Extraction Solvent" category consists exclusively of trichloroethylene. Also, all of the 4 gg/y of solvent consumed in the "Rare Metal Extraction" category corrrespond to a single solvent -methylisobutyl ketone, while special naphthas account for all of the 160 gg/y of solvent consumed in the vegetable oil extraction. Obviously neither special naphthas nor methylbutyl ketone are included in the more general category of "Extraction Solvent," which consists entirely of trichloroethylene.

TABLE 2

CLASSIFICATION OF SOLVENT END USES INTO INDUSTRIAL AND CONSUMER/COMMERCIAL USAGE SECTORS

	Nationwide Consumption gg/y (lbs x 10^6/y)*				
INDUSTRIAL USES			5,534	(12,200)	(71%)
Industrial Surface Coatings	1,820	(4,000)			
Metal Cleaning	660	(1,449)			
Adhesives, Industrial Use	465	(1,020)			
Industrial Processes	380	(836)			
Dry Cleaning	290	(638)			
Plastics	280	(621)			
Graphic Arts	270	(595)			
Rubber	210	(455)			
Resins	210	(454)			
Textiles	180	(400)			
Extraction Vegetable Oil	160	(342)			
Auto Body Refinishing	160	(352)			
Paint Removing	75	(165)			
Cleaning	74	(162)			
Acetaldehyde Process	71	(157)			
Cellulose Acetate Solvent	46	(102)			
Pharmaceutical Industry	29	(64)			
Lube Oil Refining	25	(54)			
Phillips Low Pressure Polyethylene Solvent	18	(39)			
Extraction Hardwood Pulping	15	(33)			
Electrolytic Solvent in Grignard Reaction	15	(33)			
Inks	15	(32)			
Foam Blowing	13	(28)			
Extraction, Udex	12	(26)			
Extraction Solvent	11	(25)			
Toluene Diisocyanate Process	10	(23)			
Solvent for Acetylene	10	(21)			
Extraction, Butadiene	5	(11)			
Extraction, Rare Metals	5	(10)			
CONSUMER/COMMERCIAL			1,086	(2,400)	(14%)
Architectural surface coatings	320	(707)			
Aerosol Products	292	(643)			
Household	160	(346)			
Toiletries	113	(249)			
Rubbing Compound	53	(117)			
Windshield Washing	52	(115)			
Polishes and Waxes	41	(91)			
Adhesives, non-industrial use	25	(55)			
Space Deodorant	15	(34)			
Moth Control	12	(27)			
Laundry Treatment	3	(7)			
OTHER USES			230	(508)	(3%)
Pesticides	140	(307)			
Cut-back asphalt	90	(201)			
SUBTOTAL, IDENTIFIED USES**			6,900	(15,000)	(88%)
UNIDENTIFIED USES**			900	(2,000)	(12%)
TOTAL**			7,800	(17,000)	(100%)

*gg = 10^3 mt = 10^6 kg
**rounded off to two significant figures

Similar problem of end use overlap can be noticed in the consumer/commercial category. Thus, solvent use in "Toiletries" and "Cleaning" appears to overlap with the "Aerosols" category and all of these categories are in an apparent overlap with the "Household" category. Again, reference to Table A1 will show that although many other solvents are contained in household products, the 160 gg/y of solvent from the "Household" category in Table 2 consists exclusively of special naphthas (120 gg/y) and isopropanol (40 gg/y).

3.0 CORRELATION OF SOLVENT END USES WITH THE STANDARD INDUSTRIAL CLASSIFICATION (SIC)

The SIC classification is intended to conform to the actual structure of industry as it is found to exist in the American economy. It does not therefore, follow any single principle, such as the use of the products, market structure, the nature of raw materials, etc.

The system is based on a concept of the operating establishment. An operating establishment is an economic unit which produces goods or services - for example, a farm; a mine; a factory; and a store. In most instances, the establishment is at a single physical location and it is engaged in one, or predominantly one, type of economic activity for which an industry code is applicable. A group of establishments which has significance with regard to a number of persons employed, volume of business and other economic factors such as number of establishments, payroll and value added, is recognized as an industry and assigned a unique code number.

If SIC code is to be used in conjunction with solvent emission inventory, proper distinction between the industrial processes which produce solvent containing products and the processes where these products are used is necessary. The release of the solvent to atmosphere may occur in the product manufacturing phase, or it may occur during product use (possibly as a step in another manufacturing process). Occasionally, solvents are released both during manufacture of a given product and during its subsequent use. An effort was made to correlate the solvent end uses with those SIC industries in which the solvent is actually released to the atmosphere. In this sense, the SIC code could not be conveniently applied to the end uses in the consumer/commercial sector because of a multitude of ways and locations in which these solvents are released to the atmosphere. Therefore, as far as an emission inventory is concerned, this sector corresponds to the area source. Conversely, the point sources which represent a physical location at which significant quantities of solvents are released to the atmosphere, correspond to the industrial sector in Table 2.

The industrial sector encompasses a very large number of SIC industries. For the purpose of correlation with solvent end uses it was necessary to condense these SIC industries into several major categories. These categories, designated with code numbers from 1 to 35 are presented in Table 3 along with the corresponding SIC industries.

Table 4 correlates the individual solvent end uses with these major categories. In many cases, a one-to-one relationship exists. However, in some cases one end use corresponds to many SIC categories. This is well illustrated in the case of surface coatings which covers 14 SIC categories.

TABLE 3

CLASSIFICATION OF INDUSTRIAL CATEGORIES

Code Number		Standard Industrial Classification (SIC)
1	Fats and Oils	207-
2	Alcoholic Beverages	2082, 2084, 2085
3	Dyeing and Finishing Textiles	2261, 2262, 2269
4	Fabric Coating	2295
5	Millwork, Veneer, Plywood & Structural Wood Members	243-
6	Wood Containers	244-
7	Furniture and Fixtures	25--
8	Metal Furniture	2514, 2522, 2542, 2591
9	Paper and Allied Products	26--
10	Pharmaceutical Preparations	2834
11	Specialty Cleaning, Polishing & Sanitation Preparations	2842
12	Paint Manufacturing	2851, 3952
13	Industrial Organic Chemicals	2869
14	Cyclic Crudes, Intermediates, etc.	2865
15	Adhesives	2891
16	Rubber and Plastics Products	3011, 3021, 3041
17	Fabricated Metal Products, except Machinery & Transportation Products	34--
18	Febricated Structural Metal Products	3442
19	Electrical and Electronic Machinery, Equipment and Supplies	36--
20	Major Applicances	3631, 3632, 3633
21	Small Appliances	3634, 3635, 3636
22	Transportation Equipment	37--
23	Motor Vehicles & Motor Vehicle Equipment	371-
24	Ship & Boat Building & Repairing	373-
25	Carbon Paper Manufacture	3955
26	Paint Shops (automotive repair)	7531,7535
27	Printing, Publishing & Allied Industries	27--
28	Dry Cleaning	7215, 7216, 7218
29	Rubber Manufacturing	2822, 3031, 3069
30	Plastic Materials and Synthetic Resins	282-
31	Degreasing (primary metal, machinery)	3341, 335-, 336-, 3391, 3511, 3522, 3531, 3541, 3542, 3544, 3551, 3562, 3566, 3571, 3579, 3585, 3599, 3822, 3949, 3999,
32	Miscellaneous Manufacturing	3931, 394-, 395-, 396-, 399-, 3996
33	Printing Ink	2893
34	Industrial Inorganic Chemicals	2819
35	Lubricating Oils and Greases	2992

TABLE 4

CORRELATION OF SOLVENT END USES WITH THE CONDENSED SIC CATEGORIES AND SOLVENT EMISSION QUESTIONNAIRE

Solvent End Use In The Industrial Sector	Condensed SIC Category Code Numbers*	Question Group Code Numbers**
Industrial Surface Coatings	4, 6, 7, 8, 17, 18 19, 20, 21, 22, 23, 24, 26, 32, (a)	3, 4, 5, (b)
Metal Cleaning	31	1
Adhesives (Industrial Use)	23, 19, (a)	3, 4, 5, 8, (a),(b) 8, (a), (b)
Industrial Processes	2, 9, 12, 13, 14 15, 25, 29 (a)	8, (a), (b)
Dry Cleaning	28	2
Plastics	30	8
Graphic Arts	27	7
Rubber	16, 29	8, (a), (b)
Resins	30	8, (b)
Textiles	3	8
Extraction, Vegetable Oil	1	8
Paint Removing	(c)	8, (a), (b)
Cleaning	(c)	8, (a), (b)
Acetaldehyde Process	13	8
Cellulose Acetate Solvent	13	8
Pharmaceutical Industry	10	8
Lube Oil Refining	35	8
Phillips Low Pressure Polyethylene Solvent	30	8
Extraction, Hardwood Pulp	9	8
Electrolytive Solvent in Griguard Reaction	13	8
Inks	33, 27	7, 8
Foam Blowing	30	8
Extraction, Udex	13	8
Extraction Solvent	13	8
Toluene Diisocyanate Process	13	8
Solvent for Acetylene	13	8
Extraction, Butediene	13	8
Extraction, Rare Metals	34	8

(a) The code numbers do not completely cover the corresponding end use.

(b) Solvent may be released from materials not specifically mentioned in the questionnaire. Solvent content may not be known to the user.

(c) Used in industrial maintenance in very large number of industries.

*Condensed SIC categories and the associated Code Numbers are presented in Table 3.

**Question Groups and the associated Code Numbers are presented in Table 1. They refer to the Solvent Emission Questionnaire as presented in Reference 4 (see Appendix).

4.0 SCOPE OF THE QUESTIONNAIRE

In addition to SIC codes, Table 4 also correlates the solvent end uses with the questions used in the solvent emisssion questionnaire as presented in Reference 4. For easy reference, unique question code numbers were assigned to each major group of questions in that questionnaire. These code numbers are listed in Table 1 and are used for correlation with end uses as shown in Table 4.

Practically the entire industrial solvent use sector is covered by the questionnaire. Some difficulties may be expected in the cases when the respondents do not know the solvent content of the material they are using. Such difficulties may be expected, for example, in manufacturing of rubber products, printing, application of adhesives and surface coatings.

Due to a large amount of solvent released in application of adhesives (465 gg/y), this end use merits special consideration. Those adhesive applications which utilize roller, flow, curtain, spray and knife coating techniques will be identified in that portion of the questionnaire which addresses surface coatings (Question Groups 3, 4, 5). However, there are application techniques unique to the adhesives which include gravity, capillary wick, and pressure or vacuum feeding of adhesives between prepositioned substrates. Such techniques have been used, for instances, in bonding of extruded aluminum corners of electronic equipment cabinets.[5] They are significantly different from traditional surface coating operations. Some of the adhesives related solvent usage may go unreported because it would not be specifically requested by any of the question groups. The "General Solvent Use" (Group 8) should perhaps be expanded to include, in addition to pure solvents, other materials which contain solvents.

It is interesting to see what portion of the entire domestic annual solvent consumption is covered by the individual question groups in the questionnaire. Question groups are correlated with solvent consumption in Table 5. The table shows that the

TABLE 5

BREAKDOWN OF SOLVENT CONSUMPTION IN THE INDUSTRIAL SECTOR BY INDIVIDUAL GROUPS OF QUESTIONS IN THE QUESTIONNAIRE[(a)]

Question Group Code Numbers	Question Groups	Nationwide Consumption gg/y (lbs x 10^6/y)		
1	Degreasings	660	(1,450)	(14.3%)
2	Dry Cleanings	290	(640)	(6.3%)
3	Protective or Decorative Coatings	1,820	(4,000)	(39.5%)
4	Fabric or Rubberized Coatings			
5	Miscellaneous Surface Coatings			
6	Characteristics of Ovens	-	-	-
7	Printing	270	(600)	(5.9%)
8	General Solvent Use	1,570	(3,500)	(34.0%)
9	Bulk Solvent Storage	-	-	-
	Total	4,610	(10,100)	(100%)

(a)Solvent Emission Questionnaire as presented in Reference 4 (see Appendix).

largest solvent consumption (39.5%) is associated with the combined Question Groups 3, 4 and 5. These groups are concerned with surface coatings which are broken down into protective and decorative (Group 3), fabric or rubberized (Group 4) and miscellaneous (Group 5).

Thirty-four percent of all the solvent use corresponds to the "General Solvent Use" question group (Group 8). This group covers a large number of end uses. All of these end uses, a total of 20, are listed separately in Table 6, along with the corresponding SIC code numbers for major industry groups from Table 3.

As far as solvent emission inventory is concerned, Table 6 may be more useful if the SIC code numbers were expressed in terms of end uses. This is shown in Table 7. Since many SIC code numbers correspond to several end uses and vice versa, a one-to-one correlation is often impossible. Therefore, solvent consumption corresponding to some code numbers could not be determined. Nevertheless, 70% of the 1570 gg/y of total solvent consumption associated with the "General Solvent Use" question group was directly correlated with the SIC code numbers. Four major code numbers, 1, 3, 13 and 30 account for most of this 70%. These code numbers correspond to plastic materials and synthetic resins (521 gg/y), dyeing and finishing textiles (180 gg/y), industrial organic chemicals (160 gg/y) and fats and oils (160 gg/y), respectively.

Table 7 also lists the total number of end uses which correspond to the individual code numbers. Again, relative importance of code numbers 13 and 30 is indicated by the large number of the associated solvent end uses. Thus, industrial organic chemicals (Code No.13) covers eight and plastic materials and synthetic resins (Code No.30) cover four solvent end uses. Therefore, the "General Solvent Use" question group will be most important in the questionnaires directed at the above mentioned industries with Code Numbers 1, 3, 13 and 30.

TABLE 6

SOLVENT END USES COVERED BY THE "GENERAL SOLVENT USE" PART OF THE QUESTIONNAIRE(a)

	Nationwide Consumption gg/y(b)	Condensed SIC Categories Code Numbers(c)
Industrial Processes	380	2, 9, 12, 13, 14, 15, 25, 29
Plastics	280	30
Resins	210	30
Textiles	180	3
Extraction, Vegetable Oil	160	1
Paint Removing	75	(d)
Acetaldehyde Process	71	13
Cellulose Acetate Solvent	46	13
Pharmaceutical Industry	29	10
Lube Oil Refining	25	35
Phillips Low Pressure Polyethylene Solvent	18	30
Extraction Hardwood Pulping	15	9
Electrolytic Solvent in Grignard Reaction	15	13
Foam Blowing	13	30
Extraction, Udex	12	13
Extraction Solvent	11	13
Toluene Diisocyanete Process	10	13
Solvent for Acetylene	10	13
Extraction, Butadiene	5	29
Extraction, Rare Metals	5	34
Total	1,570	

(a)Solvent emission questionnaire as presented in Reference 4 (see Appendix).

(b)gg = 10^3mt = 10^6kg

(c)Condensed SIC industry categories and their associated code numbers are presented in Table 3

(d)Used in industrial maintenance in very large number of industries.

TABLE 7

CONDENSED SIC INDUSTRY CATEGORIES COVERED BY THE "GENERAL SOLVENT USE" PART OF THE QUESTIONNAIRE (a), (b)

Condensed SIC Category Code No. (b)	Condensed SIC Industry Category(b)	Nationwide Consumption gg/y(c)	Number of Solvent End Uses To Which The Code Applies
1	Fats and Oils	160	1
2	Alcholic Beverages	(d)	1
3	Dyeing and Finishing Textiles	180	1
9	Paper and Allied Products	(d)	2
10	Pharmaceutical Preparations	29	1
12	Paint Manufacturing	(d)	1
13	Industrial Organic Chemicals	160	8
14	Cycle Crudes, Intermediates, etc.	(d)	1
15	Adhesives	(d)	1
25	Carbon Paper Manufacture	(d)	1
29	Rubber Manufacturing	(d)	2
30	Plastic Materials and Synthetic Resins	521	4
34	Industrial Inorganic Chemicals	5	1
35	Lubricating Oils and Greases	25	1
	Subtotal		1080
	Other Industries		490
	Total		1570

(a)Solvent emission questionnaire as presented in Reference 4 (see Appendix).

(b)Condensed SIC Industry Categories and their associated code numbers are presented in Table 3.

(c)gg = 10^3 mt = 10^6kg.

(d)The value could not be determined due to lack of one-to-one correspondence between industry categories and solvent end use.

5.0 AREA SOURCES

The end uses in the consumer/commercial category would, for the purpose of the VOC emission inventory, most conveniently be treated as area sources insofar as they can neither be associated with a particular SIC code nor specific location. Regional levels of solvent emissions from such sources could be determined from various statistical information, once the relationship between that statistical information and the nationwide solvent consumption patterns is established. Following are some of the parameters which may be applied:

- Number of inhabitants (per capita allocation)
- Number of people employed
- Number of people employed in industry
- Number of people employed in specific industries
- Number of people engaged in agriculture
- Number of households
- Regional consumption of electricity, water, gas, fuel
- Level of sales of specific products.

Most often, the per capita approach will be the easiest one to apply. Statistical information required for this approach is most readily available. It is likely that in some cases more specific parameters could yield improved results. However, further study on the relationship between solvent emission and these various potentially applicable parameters is needed before they can be readily used.

6.0 UNIDENTIFIED SOLVENT CONSUMPTION

The results of the solvent end uses study, presented in Table 2, show that approximately 900 gg/y of solvents is consumed in unidentified end uses. This is primarily due to the limited information on end use breakdown for the surveyed solvents. In addition, certain solvents were not included in the survey because of a lack of information regarding their production.

This unidentified solvent consumption poses a problem with regard to a solvent emission inventory. The question is whether this unidentified solvent consumption should be treated as area sources (and allocated on a per capita basis) or as both area and point sources. If this later alternative is adopted, then the relative amount of solvent consumption related to area and point sources must be determined. In addition, it must be decided how to proportionate the unknown solvent consumption to the individual point sources. The available solvent end use information is insufficient to answer these questions.

A partial solution to this difficult problem may nontheless be possible. No matter how the unidentified solvent consumption is treated, it will cause an error in solvent emission inventory. The proper question to ask is therefore: How can this error be minimized. When answering this question an important point should be kept in mind.

In most industrial as well as in most consumer/commercial applications, solvents are used as mixtures. It is reasonable to assume that the unidentified solvent consumption largely corresponds to minor solvent components in such mixtures both in industrial and consumer/commercial applications. It is likely that in the average the unidentified minor components of solvent mixtures are used in the industrial and consumer/commercial applications in the same proportions as the major components of these mixtures. Therefore, the unidentified solvent consumption should be proportioned between the area sources and the point sources in the same way as the identified solvent consumption.

In reality, these proportions may be considerably different and the assignment of the unidentified solvent consumption to the industrial and consumer/commercial sectors in this manner will very likely produce an error. However, we believe that as far as an emission inventory is concerned, this error will be significantly smaller than if the entire unidentified solvent consumption was treated as an area source and allocated on a per capita basis.

Solvent consumption in pesticides and cutback asphalt should not be considered in the above analysis because both of these end uses involve almost exclusively special naphthas and therefore, will not contain any portion of the unidentified solvent consumption.

According to Table 2, about 80% of the identified solvent consumption takes place in the industrial sector, which corresponds to the point sources, and 20% in the consumer/commercial sector corresponding to the area sources. By analogy then, 80% of the 900 gg/y of the unidentified solvent consumption should also take place in the industrial sector. This amounts to about 700 gg/y. The remaining 200 gg/y should therefore be associated with the consumer/commercial sector.

Solvent consumption in some of the industries and processes in the industrial sector, presented in Table 2 is understated. This is because some of the solvents used in these industries in minor quantities were not identified. One portion of the 700 gg/y therefore corresponds to these solvents. In addition, some of the minor industrial uses were not identified. They account for the remainder of these 700 gg/y of unidentified solvent consumption.

The present data are insufficient to allocate the unidentified industrial solvent consumption to specific industries and processes. Fortunately, this is not likely to interfere with emission inventories since it is expected that most of the unidentified solvent consumption will be adequately covered by the industrial solvent use questionnaires.

In summary, point sources will account for 80% of the total solvent consumption and area sources for 17%. The remaining 3%, corresponding to "Other Uses" (pesticides and cutback asphalt) should be allocated by special techniques. One way of obtaining information on regional levels of use of pesticides and cutback asphalt is to contact regional agricultural and transportation government agencies or institutions. Statistical information on sales of pesticides may prove valuable. Procedures for inventorying these sources are included in Reference 4.

7.0 CONCLUSIONS AND RECOMMENDATIONS

7.1 Classification of Solvent Consumption

In order that the solvent use information can be effectively utilized in VOC control programs, the identified end uses were classified in two major categories: industrial and consumer/commercial, as summarized in Table 8.

TABLE 8

SUMMARY OF SOLVENT END USE CLASSIFICATION

	Nationwide Consumption gg/y (lbs x 10^6/y)[a],[b]		
IDENTIFIED USES	6,900	(15,000)	88%
Industrial Uses (Point Sources)	5,500	(12,000)	71%
Consumer/Commercial Uses (Area Sources)	1,100	(2,400)	14%
Other Uses (Cutback Asphalt and Pesticides)	200	(500)	3%
UNIDENTIFIED USES	900	(2,000)	12%
TOTAL	7,800	(17,000)	(100%)

As far as a solvent emission inventory is concerned, the industrial end uses can be considered to correspond to point sources and the consumer/commercial sources to area sources.

7.2 Scope of Solvent Emission Questionnaire

The questionnaire, as presented in Reference 4, will cover most of the sources in the industrial sector (point sources). The "General Solvent Use" part of the questionnaire covers about one third of the solvent consumption in the industrial sector. This part should therefore be properly emphasized and provided with specific guidelines for reporting the use of materials with unknown solvent content. Information on consumption and solvent content of adhesives should be specifically requested.

(a)gg = 10^3 mt = 10^6 kg

(b)rounded off to 2 significant figures

7.3 Allocation of the Unidentified Solvent Consumption

A total of 900 gg/y of unidentified solvent consumption was allocated to the industrial and consumer/commercial sectors in the same proportion in which the identified solvent consumption is distributed between these two sectors. We believe that this would lead to smaller error in the solvent inventory than if the entire unidentified solvent consumption was treated as an area source and allocated on a per capita basis. This decision is based on the assumption that the unidentified solvent consumption largely involves minor components in solvent mixtures in both the industrial and consumer/commercial use sectors. On the average, the overall quantity of the minor components of solvent mixtures consumed in a given use sector can be expected to correspond to the overall quantity of the major components consumed in that sector. As a result, the summary of solvent end use classification presented in Table 8, can now be modified as shown in Table 9.

TABLE 9

SUMMARY OF SOLVENT END USE CLASSIFICATION WITH UNIDENTIFIED CONSUMPTION ALLOCATED TO INDUSTRIAL AND CONSUMER/COMMERCIAL SECTORS

	Nationwide Consumption gg/y	(lbs x 10^6/y)[a],[b]	
Industrial Uses (Point Sources)	6,200	(14,000)	80%
Consumer/Commercial Uses (Area Sources)	1,300	(2,900)	17%
Other Uses (Cutback Asphalt and Pesticides)	200	(500)	3%
Total	7,800	(17,000)	100%

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[a] gg = 10^3 mt = 10^6 kg

[b] rounded off to 2 significant figures

7.4 Recommended Treatment Of Area Sources

In the absence of sufficient data for application of more specific statistical relationships, a per capita determination of consumer/commercial solvent use emissions is recommended. This yields an overall nationwide area source emissions parameter of about 13 lbs of solvent per person. This number is the sum of all consumer/commercial solvent use in Table 9 (2,900 lbs x 10^6/yr) divided by the population in the United States (215 million). This total can be assumed, for the most part, to be attributable to the consumer/commercial uses identified in Table 2. It is recommended that this solvent use total be added to the industrial and other solvent uses shown in Table 2. An accurate estimate of all solvent use in the emission inventory will be obtained in this way.

The above recommendation is based on several assumptions. First, it is assumed that these consumer/commercial area sources have not been otherwise covered in the inventory based on locale-specific information (e.g. a special survey). For example, in some areas, architectural surface coatings may be covered by assuming a locally available per capita paint usage factor. If this is done, the 13 lb per capita solvent use estimate should be reduced to about 10 lb per capita so that trade paint sales are not accounted twice. However, such locale-specific information on the use and solvent content will generally not be available for the wide variety of other consumer/commercial products.

Second, it is assumed that none of the consumer/commercial area sources will be covered by the procedures used to develop emission estimates for the industrial use category in Table 2. The point source information on industrial solvent uses should be screened to see if any of the area source categories have been included.

Finally, the assumption is made that all of the industrial solvent uses in Table 2 are covered by point source inventory procedures. In fact, some of the industrial uses covered in Table 2 may be treated as area sources because of emission cutoff levels used to distinguish large and small emitters. For example, dry cleaning and cold cleaning of metal are operations that are sometimes inventoried collectively as area sources by assuming a certain level of each activity on a per capita or per employee basis. The extent that this is done in a local inventory should be determined; however, as long as any such area source estimates do not overlap with the consumer/commercial area source categories shown in Table 2, double accounting of emissions will be avoided.

REFERENCES

1. "U.S. Bureau of the Census, County Business Patterns, 1976, United States," U.S. Government Printing Office, Washington, D.C. 1978.

2. "Million Dollar Directory," Dun and Bradstreet, Inc.,New York,New York, 10019.

3. P. Morganstern, et.al., "A Methodology for Estimating Volatile Organic Compound Emissions from Industrial Sources," Prepared for the Illinois Environmental Protection Agency by Walden Division of Abcor, Inc. Presented at the 71st Annual Meeting of the American Institute of Chemical Engineers. November 1978.

4. "Procedures for the Preparation of Emission Inventories for Volatile Organic Compounds," U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina, December 1977, EPA-450/2-77-028.

5. Setzer, A.J., Graybeal, M.A., Assem.Eng.9 (7) 24 (1965).

TABLE A1. DOMESTIC ANNUAL CONSUMPTION OF SOLVENTS BY END USE

SURFACE COATINGS

TOTAL CONSUMPTION 2327 GG/Y (5120 MLBS/Y) REPRESENTS
33% OF TOTAL DOMESTIC CONSUMPTION OF ALL SOLVENTS

	YEAR	GG	MLBS	%
SPECIAL NAPHTHAS	1977	1667	3668	71
ACETONE	19 0	93	205	4
METHYL ISOBUTYL KETONE	1977	62	138	2
METHYL ETHYL KETONE	1973	177	390	7
ETHYL ACETATE	1976	46	103	2
BUTYL ACETATES	1977	40	90	1
BUTYL ALCOHOLS	1972	60	132	2
GLYCOL ETHERS	1975	67	149	2
ISOPROPANOL	1974	111	245	4

METAL CLEANING

TOTAL CONSUMPTION 658 GG/Y (1449 MLBS/Y) REPRESENTS
9% OF TOTAL DOMESTIC CONSUMPTION OF ALL SOLVENTS

	YEAR	GG	MLBS	%
SPECIAL NAPHTHAS	1977	274	604	41
METHYLENE CHLORIDE	1976	25	55	3
PERCHLOROETHYLENE	1974	54	120	8
1,1,1, TRICHLOROETHANE	1976	195	431	29
TRICHLOROETHYLENE	1978	108	239	16

ADHESIVES

TOTAL CONSUMPTION 485 GG/Y (1069 MLBS/Y) REPRESENTS
7% OF TOTAL DOMESTIC CONSUMPTION OF ALL SOLVENTS

	YEAR	GG	MLBS	%
SPECIAL NAPHTHAS	1977	418	920	86
METHYL ISOBUTYL KETONE	1977	3	8	0
METHYL ETHYL KETONE	1973	36	81	7
BUTYL ACETATES	1977	27	60	5

INDUSTRIAL PROCESSES

TOTAL CONSUMPTION 380 GG/Y (836 MLBS/Y) REPRESENTS
5% OF TOTAL DOMESTIC CONSUMPTION OF ALL SOLVENTS

	YEAR	GG	MLBS	%
SPECIAL NAPHTHAS	1977	42	94	11
ETHANOL	1975	37	82	9

```
TABLE A1.  DOMESTIC ANNUAL CONSUMPTION OF SOLVENTS
                BY END USE (CONT.)

METHANOL
                                              1977   300    660    78
           AEROSOL PRODUCTS

TOTAL CONSUMPTION  292 GG/Y ( 643 MLBS/Y) REPRESENTS
  4% OF TOTAL DOMESTIC CONSUMPTION OF ALL SOLVENTS
SPECIAL NAPHTHAS                              YEAR    GG   MLBS     %
FLUOROCARBONS                                 1977    65    145    22
CHLOROFLUOROCARBONS                           1978    74    163    25
METHYLENE CHLORIDE                            19 0   102    225    34
                                              1976    50    110    17
           DRY CLEANING

TOTAL CONSUMPTION  285 GG/Y ( 629 MLBS/Y) REPRESENTS
  4% OF TOTAL DOMESTIC CONSUMPTION OF ALL SOLVENTS
SPECIAL NAPHTHAS                              YEAR    GG   MLBS     %
PERCHLOROETHYLENE                             1977   240    529    84
                                              1974    45    100    15
           PLASTICS

TOTAL CONSUMPTION  282 GG/Y ( 622 MLBS/Y) REPRESENTS
  4% OF TOTAL DOMESTIC CONSUMPTION OF ALL SOLVENTS
SPECIAL NAPHTHAS                              YEAR    GG   MLBS     %
ETHYL ACETATE                                 1977   274    603    96
                                              1976     8     19     3
           GRAPHIC ARTS

TOTAL CONSUMPTION  270 GG/Y ( 595 MLBS/Y) REPRESENTS
  3% OF TOTAL DOMESTIC CONSUMPTION OF ALL SOLVENTS
SPECIAL NAPHTHAS                              YEAR    GG   MLBS     %
GLYCOL ETHERS                                 1977   266    587    98
                                              1975     3      8     1
           RUBBER

TOTAL CONSUMPTION  209 GG/Y ( 461 MLBS/Y) REPRESENTS
  3% OF TOTAL DOMESTIC CONSUMPTION OF ALL SOLVENTS
```

TABLE A1. DOMESTIC ANNUAL CONSUMPTION OF SOLVENTS
BY END USE (CONT.)

	YEAR	GG	MLBS	%
SPECIAL NAPHTHAS	1977	207	456	98
ETHYLENE DICHLORIDE	1977	2	5	1

RESINS

TOTAL CONSUMPTION 206 GG/Y (455 MLBS/Y) REPRESENTS
3% OF TOTAL DOMESTIC CONSUMPTION OF ALL SOLVENTS

	YEAR	GG	MLBS	%
SPECIAL NAPHTHAS	1977	196	433	95
ETHANOL	1975	10	22	4

TEXTILES

TOTAL CONSUMPTION 181 GG/Y (400 MLBS/Y) REPRESENTS
2% OF TOTAL DOMESTIC CONSUMPTION OF ALL SOLVENTS

	YEAR	GG	MLBS	%
PERCHLOROETHYLENE	1974	181	400	100

HOUSEHOLD

TOTAL CONSUMPTION 157 GG/Y (346 MLBS/Y) REPRESENTS
2% OF TOTAL DOMESTIC CONSUMPTION OF ALL SOLVENTS

	YEAR	GG	MLBS	%
SPECIAL NAPHTHAS	1977	120	265	76
ISOPROPANOL	1974	36	81	23

EXTRACTION , VEGETABLE OIL

TOTAL CONSUMPTION 155 GG/Y (342 MLBS/Y) REPRESENTS
2% OF TOTAL DOMESTIC CONSUMPTION OF ALL SOLVENTS

	YEAR	GG	MLBS	%
SPECIAL NAPHTHAS	1977	155	342	100

PESTICIDES

TOTAL CONSUMPTION 140 GG/Y (308 MLBS/Y) REPRESENTS
2% OF TOTAL DOMESTIC CONSUMPTION OF ALL SOLVENTS

YEAR	GG	MLBS	%

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TABLE A1.  DOMESTIC ANNUAL CONSUMPTION OF SOLVENTS
                  BY END USE (CONT.)


SPECIAL NAPHTHAS                                1977  140   308  100

          TOILETRIES

TOTAL CONSUMPTION  113 GG/Y ( 249 MLBS/Y) REPRESENTS
  1% OF TOTAL DOMESTIC CONSUMPTION OF ALL SOLVENTS
                                                YEAR   GG  MLBS    %
ETHANOL                                         1975  113   249  100

          ASPHALT COMPOUNDS

TOTAL CONSUMPTION   91 GG/Y ( 202 MLBS/Y) REPRESENTS
  1% OF TOTAL DOMESTIC CONSUMPTION OF ALL SOLVENTS
                                                YEAR   GG  MLBS    %
SPECIAL NAPHTHAS                                1977   91   202  100

          PAINT REMOVING

TOTAL CONSUMPTION   75 GG/Y ( 165 MLBS/Y) REPRESENTS
  1% OF TOTAL DOMESTIC CONSUMPTION OF ALL SOLVENTS
                                                YEAR   GG  MLBS    %
METHYLENE CHLORIDE                              1976   75   165  100

          CLEANING

TOTAL CONSUMPTION   73 GG/Y ( 162 MLBS/Y) REPRESENTS
  1% OF TOTAL DOMESTIC CONSUMPTION OF ALL SOLVENTS
                                                YEAR   GG  MLBS    %
ETHANOL                                         1975   63   139   85
GLYCOL ETHERS                                   1975   10    23   14

          ACETALDEHYDE PROCESS

TOTAL CONSUMPTION   71 GG/Y ( 157 MLBS/Y) REPRESENTS
  1% OF TOTAL DOMESTIC CONSUMPTION OF ALL SOLVENTS
                                                YEAR   GG  MLBS    %
ETHANOL                                         1975   71   157  100
```

TABLE A1. DOMESTIC ANNUAL CONSUMPTION OF SOLVENTS BY END USE (CONT.)

RUBBING COMPOUND

TOTAL CONSUMPTION 53 GG/Y (117 MLBS/Y) REPRESENTS 0% OF TOTAL DOMESTIC CONSUMPTION OF ALL SOLVENTS

	YEAR	GG	MLBS	%
ISOPROPANOL	1974	53	117	100

WINDSHIELD WASHING

TOTAL CONSUMPTION 52 GG/Y (115 MLBS/Y) REPRESENTS 0% OF TOTAL DOMESTIC CONSUMPTION OF ALL SOLVENTS

	YEAR	GG	MLBS	%
METHANOL	1977	52	115	100

CELLULOSE ACETATE SOLVENT

TOTAL CONSUMPTION 46 GG/Y (102 MLBS/Y) REPRESENTS 0% OF TOTAL DOMESTIC CONSUMPTION OF ALL SOLVENTS

	YEAR	GG	MLBS	%
ACETONE	19 0	46	102	100

POLISHES AND WAXES

TOTAL CONSUMPTION 41 GG/Y (91 MLBS/Y) REPRESENTS 0% OF TOTAL DOMESTIC CONSUMPTION OF ALL SOLVENTS

	YEAR	GG	MLBS	%
SPECIAL NAPHTHAS	1977	27	61	67
1,1,1, TRICHLOROETHANE	1976	13	30	32

PHARMACEUTICAL INDUSTRY

TOTAL CONSUMPTION 29 GG/Y (65 MLBS/Y) REPRESENTS 0% OF TOTAL DOMESTIC CONSUMPTION OF ALL SOLVENTS

	YEAR	GG	MLBS	%
SPECIAL NAPHTHAS	1977	4	9	13
ACETONE	19 0	3	7	10
METHYLENE CHLORIDE	1976	11	25	38
METHANOL	1977	6	15	23
DIMETHYL FORMAMIDE	19 0	2	6	9
AMYL ALCOHOL	19 0	1	3	4

TABLE A1. DOMESTIC ANNUAL CONSUMPTION OF SOLVENTS BY END USE (CONT.)

```
           LUBE OIL REFINING

TOTAL CONSUMPTION   24 GG/Y (  54 MLBS/Y) REPRESENTS
  0% OF TOTAL DOMESTIC CONSUMPTION OF ALL SOLVENTS
                                       YEAR   GG  MLBS    %
METHYL ETHYL KETONE                    1973   18    41   75
FURFURAL                               1975    5    13   24

           SPACE DEODORANT

TOTAL CONSUMPTION   15 GG/Y (  34 MLBS/Y) REPRESENTS
  0% OF TOTAL DOMESTIC CONSUMPTION OF ALL SOLVENTS
                                       YEAR   GG  MLBS    %
P - DICHLOROBENZENE                    1973   15    34  100

           EXTRACTION , HARDWOOD PULPING

TOTAL CONSUMPTION   15 GG/Y (  33 MLBS/Y) REPRESENTS
  0% OF TOTAL DOMESTIC CONSUMPTION OF ALL SOLVENTS
                                       YEAR   GG  MLBS    %
METHYL ETHYL KETONE                    1973   15    33  100

           ELECTROLYTIC SOLVENT IN GRIGNARD REACTIO

TOTAL CONSUMPTION   15 GG/Y (  33 MLBS/Y) REPRESENTS
  0% OF TOTAL DOMESTIC CONSUMPTION OF ALL SOLVENTS
                                       YEAR   GG  MLBS    %
TETRAHYDROFURAN                        1973   15    33  100

           INKS

TOTAL CONSUMPTION   14 GG/Y (  32 MLBS/Y) REPRESENTS
  0% OF TOTAL DOMESTIC CONSUMPTION OF ALL SOLVENTS
                                       YEAR   GG  MLBS    %
ETHYL ACETATE                          1976   14    32  100

           FOAM BLOWING

TOTAL CONSUMPTION   12 GG/Y (  28 MLBS/Y) REPRESENTS
  0% OF TOTAL DOMESTIC CONSUMPTION OF ALL SOLVENTS
```

TABLE A1. DOMESTIC ANNUAL CONSUMPTION OF SOLVENTS
BY END USE (CONT.)

	YEAR	GG	MLBS	%
FLUOROCARBONS	1978	12	28	100

MOTH CONTROL

TOTAL CONSUMPTION 12 GG/Y (27 MLBS/Y) REPRESENTS
0% OF TOTAL DOMESTIC CONSUMPTION OF ALL SOLVENTS

	YEAR	GG	MLBS	%
P - DICHLOROBENZENE	1973	12	27	100

EXTRACTION, UDEX

TOTAL CONSUMPTION 11 GG/Y (26 MLBS/Y) REPRESENTS
0% OF TOTAL DOMESTIC CONSUMPTION OF ALL SOLVENTS

	YEAR	GG	MLBS	%
TRIETHYLENE GLYCOL	1976	2	6	23
DIETHYLENE GLYCOL	1976	9	20	76

EXTRACTION SOLVENT

TOTAL CONSUMPTION 11 GG/Y (25 MLBS/Y) REPRESENTS
0% OF TOTAL DOMESTIC CONSUMPTION OF ALL SOLVENTS

	YEAR	GG	MLBS	%
TRICHLOROETHYLENE	1978	11	25	100

TOLUENE DIISOCYANATE PROCESS

TOTAL CONSUMPTION 10 GG/Y (23 MLBS/Y) REPRESENTS
0% OF TOTAL DOMESTIC CONSUMPTION OF ALL SOLVENTS

	YEAR	GG	MLBS	%
O-DICHLOROBENZENE	19 0	5	11	47
P - DICHLOROBENZENE	1973	5	12	52

SOLVENT FOR ACETYLENE

TOTAL CONSUMPTION 9 GG/Y (21 MLBS/Y) REPRESENTS
0% OF TOTAL DOMESTIC CONSUMPTION OF ALL SOLVENTS

	YEAR	GG	MLBS	%
ACETONE	19 0	9	21	100

TABLE A1. DOMESTIC ANNUAL CONSUMPTION OF SOLVENTS BY END USE (CONT.)

EXTRACTION,BUTADIENE

TOTAL CONSUMPTION 5 GG/Y (11 MLBS/Y) REPRESENTS
0% OF TOTAL DOMESTIC CONSUMPTION OF ALL SOLVENTS

	YEAR	GG	MLBS	%
FURFURAL	1975	5	11	100

EXTRACTION , RARE METALS

TOTAL CONSUMPTION 4 GG/Y (10 MLBS/Y) REPRESENTS
0% OF TOTAL DOMESTIC CONSUMPTION OF ALL SOLVENTS

	YEAR	GG	MLBS	%
METHYL ISOBUTYL KETONE	1977	4	10	100

LAUNDRY TREATMENT

TOTAL CONSUMPTION 3 GG/Y (7 MLBS/Y) REPRESENTS
0% OF TOTAL DOMESTIC CONSUMPTION OF ALL SOLVENTS

	YEAR	GG	MLBS	%
PERCHLOROETHYLENE	1974	3	7	100

TABLE A1. DOMESTIC ANNUAL CONSUMPTION OF SOLVENTS
BY END USE (CONT.)

GG= ONE THOUSAND METRIC TONS = ONE MILLION KILOGRAMS

MLBS= ONE MILLION POUNDS

%= CONSUMPTION OF INDIVIDUAL SOLVENTS AS PERCENTAGE OF TOTAL SOLVENT CONSUMPTION FOR GIVEN END USE

APPENDIX A 2

DOMESTIC ANNUAL CONSUMPTION OF SOLVENTS

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TABLE A2. DOMESTIC ANNUAL CONSUMPTION OF SOLVENTS (CONT.)

GG= ONE THOUSAND METRIC TONS = ONE MILLION KILOGRAMS

MLBS= ONE MILLION POUNDS

%A= CONSUMPTION OF INDIVIDUAL SOLVENT AS A PERCENTAGE OF THE TOTAL SOLVENT CONSUMPTION (OF ALL SOLVENTS)

%B= CONSUMPTION OF INDIVIDUAL SOLVENT IN STRICTLY SOLVENT USES AS A PERCENTAGE OF ITS TOTAL CONSUMPTION WHICH MAY INCLUDE "NON-SOLVENT" USES

%C= CONSUMPTION OF INDIVIDUAL SOLVENT IN IDENTIFIED END USES AS A PERCENTAGE OF ITS TOTAL CONSUMPTION AS A SOLVENT

%D= CONSUMPTION OF INDIVIDUAL SOLVENT IN UNIDENTIFIED END USES AS A PERCENTAGE OF ITS TOTAL CONSUMPTION AS SOLVENT

%E= CONSUMPTION OF INDIVIDUAL SOLVENT INCLUDING "NON-SOLVENT" USES AS A PERCENTAGE OF THE TOTAL CONSUMPTION (OF ALL SOLVENTS) INCLUDING "NON-SOLVENT" USES

%F= CONSUMPTION OF THE INDIVIDUAL SOLVENT IN A GIVEN END USE AS PERCENTAGE OF THAT SOLVENT"S TOTAL CONSUMPTION (EXCLUDING "NON-SOLVENT" USE)

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TABLE A2. DOMESTIC ANNUAL CONSUMPTION OF SOLVENTS (CONT.)

ISOPROPYL ACETATE

```
TOTAL DOMESTIC CONSUMPTION  (1968)

   AS SOLVENT         IDENTIFIED       UNIDENTIFIED      INCL. NONSOLVENT
GG/MLBS %A   %B    GG/MLBS %A  %C    GG/MLBS %A  %D      GG/MLBS %E
  18       0 100     0       0   0     18      3 100       18      0
  40                 0                 40                  40

END USES
                                              YEAR     GG  MLBS  %F
```

DIETHYLENE GLYCOL

```
TOTAL DOMESTIC CONSUMPTION  (1976)

   AS SOLVENT         IDENTIFIED       UNIDENTIFIED      INCL. NONSOLVENT
GG/MLBS %A   %B    GG/MLBS %A  %C    GG/MLBS %A  %D      GG/MLBS %E
  10       0   6     9       0  90      0      0   9      143      0
  22                20                  2                 315

END USES
                                              YEAR     GG  MLBS  %F
EXTRACTION, UDEX                               1976     9    20  90
```

TRIETHYLAMINE

```
TOTAL DOMESTIC CONSUMPTION  (1973)

   AS SOLVENT         IDENTIFIED       UNIDENTIFIED      INCL. NONSOLVENT
GG/MLBS %A   %B    GG/MLBS %A  %C    GG/MLBS %A  %D      GG/MLBS %E
  13       0 100     0       0   0     13      2 100       13      0
  29                 0                 29                  29

END USES
                                              YEAR     GG  MLBS  %F
```

```
TABLE A2. DOMESTIC ANNUAL CONSUMPTION OF SOLVENTS  (CONT.)

                      TETRAHYDROFURAN

TOTAL DOMESTIC CONSUMPTION  (1973)

  AS SOLVENT        IDENTIFIED       UNIDENTIFIED      INCL. NONSOLVENT
GG/MLBS %A  %B    GG/MLBS %A %C    GG/MLBS %A %D      GG/MLBS %E
 37      0 100     15      0  40    22      3  59       37      0
 82                33               49                  82

END USES

                                               YEAR    GG   MLBS   %F
ELECTROLYTIC SOLVENT IN GRIGNARD REACTI01973    15     33   40

                      ISOPROPANOL

TOTAL DOMESTIC CONSUMPTION  (1978)

  AS SOLVENT        IDENTIFIED       UNIDENTIFIED      INCL. NONSOLVENT
GG/MLBS %A  %B    GG/MLBS %A %C    GG/MLBS %A %D      GG/MLBS %E
 315     4  35    201      2  63    113     19  36      877      3
 693              443               250                1930

END USES

                                            YEAR    GG   MLBS   %F
HOUSEHOLD
RUBBING COMPOUND                             1974    36     81   11
SURFACE COATINGS                             1974    53    117   16
                                             1974   111    245   35

                      TRIETHYLENE GLYCOL

TOTAL DOMESTIC CONSUMPTION  (1976)

  AS SOLVENT        IDENTIFIED       UNIDENTIFIED      INCL. NONSOLVENT
GG/MLBS %A  %B    GG/MLBS %A %C    GG/MLBS %A %D      GG/MLBS %E
 10      0  20      2      0  25     8      1  75       54      0
 24                 6               18                 120

END USES

                                            YEAR    GG   MLBS   %F
EXTRACTION, UDEX                             1976     2      6   25
```

TABLE A2. DOMESTIC ANNUAL CONSUMPTION OF SOLVENTS (CONT.)

END USES

	YEAR	GG	MLBS	%F
SPACE DEODORANT	1973	15	34	42
MOTH CONTROL	1973	12	27	33
TOLUENE DIISOCYANATE PROCESS	1973	5	12	14

ETHYL BENZENE

TOTAL DOMESTIC CONSUMPTION (1975)

AS SOLVENT			IDENTIFIED			UNIDENTIFIED			INCL. NONSOLVENT	
GG/MLBS	%A	%B	GG/MLBS	%A	%C	GG/MLBS	%A	%D	GG/MLBS	%E
18	0	0	0	0	0	18	3	100	2485	11
40			0			40			5467	

END USES

	YEAR	GG	MLBS	%F

GLYCOL ETHERS

TOTAL DOMESTIC CONSUMPTION (1975)

AS SOLVENT			IDENTIFIED			UNIDENTIFIED			INCL. NONSOLVENT	
GG/MLBS	%A	%B	GG/MLBS	%A	%C	GG/MLBS	%A	%D	GG/MLBS	%E
111	1	47	81	1	73	30	5	26	236	1
246			180			66			521	

END USES

	YEAR	GG	MLBS	%F
SURFACE COATINGS	1975	67	149	60
GRAPHIC ARTS	1975	3	8	3
CLEANING	1975	10	23	9

FURFURAL

TOTAL DOMESTIC CONSUMPTION (1975)

AS SOLVENT			IDENTIFIED			UNIDENTIFIED			INCL. NONSOLVENT	
GG/MLBS	%A	%B	GG/MLBS	%A	%C	GG/MLBS	%A	%D	GG/MLBS	%E
10	0	15	10	0	100	0	0	0	69	0
24			24			0			153	

END USES

	YEAR	GG	MLBS	%F
LUBE OIL REFINING	1975	5	13	54
EXTRACTION,BUTADIENE	1975	5	11	45

```
       TABLE A2. DOMESTIC ANNUAL CONSUMPTION OF SOLVENTS  (CONT.)

                             O-DICHLOROBENZENE

TOTAL DOMESTIC CONSUMPTION   (1976)

   AS SOLVENT       IDENTIFIED    UNIDENTIFIED    INCL. NONSOLVENT
GG/MLBS %A   %B  GG/MLBS %A %C  GG/MLBS %A %D     GG/MLBS %E
   8      0  24     5     0  61    3     0  38       34     0
  18               11              7                 75

END USES
                                                YEAR    GG   MLBS   %F
TOLUENE DIISOCYANATE PROCESS                     19 0    5     11   61

                              CYCLOHEXANOL

TOTAL DOMESTIC CONSUMPTION   (1973)

   AS SOLVENT       IDENTIFIED    UNIDENTIFIED    INCL. NONSOLVENT
GG/MLBS %A   %B  GG/MLBS %A %C  GG/MLBS %A %D     GG/MLBS %E
   0      0   0     0     0   0    0     0   0      325     1
   0                0              0                717

END USES
                                                YEAR    GG   MLBS   %F

                              CYCLOHEXANONE

TOTAL DOMESTIC CONSUMPTION   (1974)

   AS SOLVENT       IDENTIFIED    UNIDENTIFIED    INCL. NONSOLVENT
GG/MLBS %A   %B  GG/MLBS %A %C  GG/MLBS %A %D     GG/MLBS %E
   0      0   0     0     0   0    0     0   0      295     1
   0                0              0                650

END USES
                                                YEAR    GG   MLBS   %F

                              P - DICHLOROBENZENE

TOTAL DOMESTIC CONSUMPTION   (1976)

   AS SOLVENT       IDENTIFIED    UNIDENTIFIED    INCL. NONSOLVENT
GG/MLBS %A   %B  GG/MLBS %A %C  GG/MLBS %A %D     GG/MLBS %E
  36      0 100    33     0  91    3     0   8       36     0
  80               73              7                 80
```

TABLE A2. DOMESTIC ANNUAL CONSUMPTION OF SOLVENTS (CONT.)

END USES	YEAR	GG	MLBS	%F
SURFACE COATINGS	1976	46	103	66
PLASTICS	1976	8	19	12
INKS	1976	14	32	20

AMYL ACETATES

TOTAL DOMESTIC CONSUMPTION (1973)

AS SOLVENT			IDENTIFIED			UNIDENTIFIED			INCL. NONSOLVENT	
GG/MLBS	%A	%B	GG/MLBS	%A	%C	GG/MLBS	%A	%D	GG/MLBS	%E
5	0	100	0	0	0	5	0	100	5	0
12			0			12			12	

END USES	YEAR	GG	MLBS	%F

BUTYL ACETATES

TOTAL DOMESTIC CONSUMPTION (19 0)

AS SOLVENT			IDENTIFIED			UNIDENTIFIED			INCL. NONSOLVENT	
GG/MLBS	%A	%B	GG/MLBS	%A	%C	GG/MLBS	%A	%D	GG/MLBS	%E
68	0	100	68	0	100	0	0	0	68	0
150			150			0			150	

END USES	YEAR	GG	MLBS	%F
SURFACE COATINGS	1977	40	90	59
ADHESIVES	1977	27	60	39

BUTYL ALCOHOLS

TOTAL DOMESTIC CONSUMPTION (1975)

AS SOLVENT			IDENTIFIED			UNIDENTIFIED			INCL. NONSOLVENT	
GG/MLBS	%A	%B	GG/MLBS	%A	%C	GG/MLBS	%A	%D	GG/MLBS	%E
105	1	9	60	0	56	45	7	43	1131	5
232			132			100			2490	

END USES	YEAR	GG	MLBS	%F
SURFACE COATINGS	1972	60	132	56

TABLE A2. DOMESTIC ANNUAL CONSUMPTION OF SOLVENTS (CONT.)

METHYL ISOBUTYL KETONE

TOTAL DOMESTIC CONSUMPTION (1977)

AS SOLVENT			IDENTIFIED			UNIDENTIFIED			INCL. NONSOLVENT	
GG/MLBS	%A	%B	GG/MLBS	%A	%C	GG/MLBS	%A	%D	GG/MLBS	%E
80	1	89	70	1	88	9	1	11	89	0
176			156			20			197	

END USES

	YEAR	GG	MLBS	%F
ADHESIVES	1977	3	8	4
SURFACE COATINGS	1977	62	138	78
EXTRACTION , RARE METALS	1977	4	10	5

1,1,1, TRICHLOROETHANE

TOTAL DOMESTIC CONSUMPTION (19 0)

AS SOLVENT			IDENTIFIED			UNIDENTIFIED			INCL. NONSOLVENT	
GG/MLBS	%A	%B	GG/MLBS	%A	%C	GG/MLBS	%A	%D	GG/MLBS	%E
209	2	80	209	3	100	0	0	0	261	1
461			461			0			575	

END USES

	YEAR	GG	MLBS	%F
METAL CLEANING	1976	195	431	93
POLISHES AND WAXES	1976	13	30	6

METHYL ETHYL KETONE

TOTAL DOMESTIC CONSUMPTION (1973)

AS SOLVENT			IDENTIFIED			UNIDENTIFIED			INCL. NONSOLVENT	
GG/MLBS	%A	%B	GG/MLBS	%A	%C	GG/MLBS	%A	%D	GG/MLBS	%E
247	3	100	247	3	100	0	0	0	247	1
545			545			0			545	

END USES

	YEAR	GG	MLBS	%F
SURFACE COATINGS	1973	177	390	71
ADHESIVES	1973	36	81	14
LUBE OIL REFINING	1973	18	41	7
EXTRACTION , HARDWOOD PULPING	1973	15	33	6

TABLE A2. DOMESTIC ANNUAL CONSUMPTION OF SOLVENTS (CONT.)

TRICHLOROETHYLENE

```
TOTAL DOMESTIC CONSUMPTION  (1978)

   AS SOLVENT        IDENTIFIED      UNIDENTIFIED    INCL. NONSOLVENT
GG/MLBS %A   %B   GG/MLBS %A %C   GG/MLBS %A %D      GG/MLBS %E
 124       1  99   120      1  96     4      0   3     125      0
 274               264               10                275

END USES
                                            YEAR    GG   MLBS   %F
METAL CLEANING                              1978   108    239   87
EXTRACTION SOLVENT                          1978    11     25    9
```

NITROBENZENE

```
TOTAL DOMESTIC CONSUMPTION  (1976)

   AS SOLVENT        IDENTIFIED      UNIDENTIFIED    INCL. NONSOLVENT
GG/MLBS %A   %B   GG/MLBS %A %C   GG/MLBS %A %D      GG/MLBS %E
   2       0   0    0       0   0     2       0 100    325      1
   5                0                 5                715

END USES
                                            YEAR    GG   MLBS   %F
```

CHLOROBENZENE

```
TOTAL DOMESTIC CONSUMPTION  (1977)

   AS SOLVENT        IDENTIFIED      UNIDENTIFIED    INCL. NONSOLVENT
GG/MLBS %A   %B   GG/MLBS %A %C   GG/MLBS %A %D      GG/MLBS %E
  45       0  30    0       0   0    45       7 100    150      0
  99                0                99                330

END USES
                                            YEAR    GG   MLBS   %F
```

ETHYL ACETATE

```
TOTAL DOMESTIC CONSUMPTION  (1976)

   AS SOLVENT        IDENTIFIED      UNIDENTIFIED    INCL. NONSOLVENT
GG/MLBS %A   %B   GG/MLBS %A %C   GG/MLBS %A %D      GG/MLBS %E
  70       0  96   70       1 100     0       0   0     72      0
 154               154                0                159
```

TABLE A2. DOMESTIC ANNUAL CONSUMPTION OF SOLVENTS (CONT.)

METHYLENE CHLORIDE

TOTAL DOMESTIC CONSUMPTION (1976)

AS SOLVENT			IDENTIFIED			UNIDENTIFIED			INCL. NONSOLVENT	
GG/MLBS	%A	%B	GG/MLBS	%A	%C	GG/MLBS	%A	%D	GG/MLBS	%E
176	2	70	161	2	91	15	2	8	250	1
388			355			33			550	

END USES

	YEAR	GG	MLBS	%F
PAINT REMOVING	1976	75	165	42
METAL CLEANING	1976	25	55	14
AEROSOL PRODUCTS	1976	50	110	28
PHARMACEUTICAL INDUSTRY	1976	11	25	6

PERCHLOROETHYLENE

TOTAL DOMESTIC CONSUMPTION (1974)

AS SOLVENT			IDENTIFIED			UNIDENTIFIED			INCL. NONSOLVENT	
GG/MLBS	%A	%B	GG/MLBS	%A	%C	GG/MLBS	%A	%D	GG/MLBS	%E
291	3	88	285	4	97	6	1	2	330	1
642			627			15			728	

END USES

	YEAR	GG	MLBS	%F
DRY CLEANING	1974	45	100	15
METAL CLEANING	1974	54	120	18
LAUNDRY TREATMENT	1974	3	7	1
SILICONES	1974	0	0	0
TEXTILES	1974	181	400	62

METHANOL

TOTAL DOMESTIC CONSUMPTION (1977)

AS SOLVENT			IDENTIFIED			UNIDENTIFIED			INCL. NONSOLVENT	
GG/MLBS	%A	%B	GG/MLBS	%A	%C	GG/MLBS	%A	%D	GG/MLBS	%E
389	5	12	359	5	92	30	5	7	3000	13
856			790			66			6600	

END USES

	YEAR	GG	MLBS	%F
INDUSTRIAL PROCESSES	1977	300	660	77
WINDSHIELD WASHING	1977	52	115	13
PHARMACEUTICAL INDUSTRY	1977	6	15	1

TABLE A2. DOMESTIC ANNUAL CONSUMPTION OF SOLVENTS (CONT.)

FLUOROCARBONS

TOTAL DOMESTIC CONSUMPTION (1978)

AS SOLVENT			IDENTIFIED			UNIDENTIFIED			INCL. NONSOLVENT	
GG/MLBS	%A	%B	GG/MLBS	%A	%C	GG/MLBS	%A	%D	GG/MLBS	%E
108	1	35	86	1	80	21	3	19	309	1
238			191			47			680	

END USES

	YEAR	GG	MLBS	%F
AEROSOL PRODUCTS	1978	74	163	68
FOAM BLOWING	1978	12	28	11

ACETONE

TOTAL DOMESTIC CONSUMPTION (1977)

AS SOLVENT			IDENTIFIED			UNIDENTIFIED			INCL. NONSOLVENT	
GG/MLBS	%A	%B	GG/MLBS	%A	%C	GG/MLBS	%A	%D	GG/MLBS	%E
186	2	20	152	2	81	34	5	18	931	4
410			335			75			2050	

END USES

	YEAR	GG	MLBS	%F
SURFACE COATINGS	19 0	93	205	50
CELLULOSE ACETATE SOLVENT	19 0	46	102	24
SOLVENT FOR ACETYLENE	19 0	9	21	5
PHARMACEUTICAL INDUSTRY	19 0	3	7	1

ETHYLENE DICHLORIDE

TOTAL DOMESTIC CONSUMPTION (1977)

AS SOLVENT			IDENTIFIED			UNIDENTIFIED			INCL. NONSOLVENT	
GG/MLBS	%A	%B	GG/MLBS	%A	%C	GG/MLBS	%A	%D	GG/MLBS	%E
5	0	0	2	0	38	3	0	61	5681	25
13			5			8			12500	

END USES

	YEAR	GG	MLBS	%F
RUBBER	1977	2	5	38

TABLE A2. DOMESTIC ANNUAL CONSUMPTION OF SOLVENTS

SPECIAL NAPHTHAS

TOTAL DOMESTIC CONSUMPTION (1977)

AS SOLVENT			IDENTIFIED			UNIDENTIFIED			INCL. NONSOLVENT	
GG/MLBS	%A	%B	GG/MLBS	%A	%C	GG/MLBS	%A	%D	GG/MLBS	%E
4319	55	99	4193	61	97	125	21	2	4320	19
9503			9226			277			9504	

END USES

	YEAR	GG	MLBS	%F
SURFACE COATINGS	1977	1667	3668	38
METAL CLEANING	1977	274	604	6
DRY CLEANING	1977	240	529	5
GRAPHIC ARTS	1977	266	587	6
RUBBER	1977	207	456	4
PLASTICS	1977	274	603	6
EXTRACTION , VEGETABLE OIL	1977	155	342	3
ADHESIVES	1977	418	920	9
INDUSTRIAL PROCESSES	1977	42	94	0
PHARMACEUTICAL INDUSTRY	1977	4	9	0
RESINS	1977	196	433	4
AEROSOL PRODUCTS	1977	65	145	1
ASPHALT COMPOUNDS	1977	91	202	2
PESTICIDES	1977	140	308	3
HOUSEHOLD	1977	120	265	2
POLISHES AND WAXES	1977	27	61	0

ETHANOL

TOTAL DOMESTIC CONSUMPTION (1975)

AS SOLVENT			IDENTIFIED			UNIDENTIFIED			INCL. NONSOLVENT	
GG/MLBS	%A	%B	GG/MLBS	%A	%C	GG/MLBS	%A	%D	GG/MLBS	%E
295	3	49	295	4	100	0	0	0	593	2
649			649			0			1305	

END USES

	YEAR	GG	MLBS	%F
RESINS	1975	10	22	3
CLEANING	1975	63	139	21
TOILETRIES	1975	113	249	38
ACETALDEHYDE PROCESS	1975	71	157	24
INDUSTRIAL PROCESSES	1975	37	82	12

APPENDIX A 3

EXAMPLE OF A TYPICAL SOLVENT EMISSION QUESTIONNAIRE*

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*"Procedures for the Preparation of Emission Inventories for Volatile Organic Compounds," U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina, December 1977, EPA-450/2-77-028.

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Example Cover Letter

(Mailing list address) (Agency address)

RE: Source Questionnaire

Dear Sir(s):

The (agency or department) is currently conducting an inventory of atmospheric emissions of volatile organic compounds from stationary sources in (geographical area). Your cooperation is required under (statute) to provide information necessary to assess volatile organic compound emissions from equipment and processes in your plant by completing the enclosed questionnaire.

Certain emission-related data on your equipment or processes have been extracted from available records. The information requested on the enclosed forms is not available from current agency records and is needed to assess current base line emissions, control potential, and to project future emissions. Your assistance will improve the accuracy of the survey. Please complete the enclosed questionnaire and return it within (time period) to the address indicated on the form.

Any questions regarding these forms should be directed to

(name, address, phone number)

Your cooperation in providing the requested information within (number) weeks from receipt of this letter will contribute materially to the accurate assessment of emissions in (area). Thank you for your assistance.

Sincerely

(name and title)

Attachments

Figure 4-1 Example Questionnaire Package

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GENERAL INSTRUCTION

ORGANIC SOLVENT SOURCE QUESTIONNAIRE

1. All questions should be directed to (name, address, phone number)

2. This questionnaire is aimed at obtaining information from a wide variety of solvent users. The complete questionnaire includes the following pages:

   Page A - GENERAL INFORMATION
   B - DEGREASING OPERATIONS
   C - DRY CLEANING OPERATIONS
   D - PROTECTIVE OR DECORATIVE COATINGS
   E - FABRIC OR RUBBERIZED COATINGS
   F - MISCELLANEOUS SURFACE COATINGS
   G - OVENS
   H - PRINTING
   I - GENERAL SOLVENT USE
   J - BULK SOLVENT STORAGE
   K - CONTROL AND STACK INFORMATION

3. Data should reflect calendar year (year) or whichever is more readily available. Specify any other 12-month period that may be used.

4. Fill in the descriptive information and amount of solvent or solvent containing materials used for each device operating under county permit as shown in the example on each page. (Note: these examples are for illustration only and may not represent actual operating conditions.)

5. In the event that data are not available on an individual device basis, use best estimates from total plant usage to complete Item 4.

6. If the type(s) and/or percentages of solvents in coatings, inks, etc. are not known, include sufficient information on the manufacturer, type and stock number so that this breakdown can be obtained. A copy of a supplier's invoice would be adequate.

7. Complete Pages I, J and K.

8. The emissions data that will be generated during this program will generally be public information. If certain process, operation, or material information is considered confidential and should be considered a trade secret, indicate such (specify a procedure and specify how confidential data will be handled).

Fig. 4-1 (cont'd.)

Reproduced from best available copy.

ORGANIC COMPOUND EMISSIONS QUESTIONNAIRE

Mail Questionnaires in the
Enclosed Envelope To:

Please Address All Questions To:

NOTE: ALL DATA SHOULD REPRESENT CALENDAR YEAR

GENERAL INFORMATION

Company Name ____________________

Plant Address ____________ City ____________ Zip ______

Mailing Address ____________ City ____________ Zip ______

Person to Contact About Form ____________________

Telephone ____________ Title ____________

Approximate Number of Employees ______

Nature of Business (Include SIC) ____________________

____

Normal Operating Schedule for Calendar Year ______

______ Hrs/Day ______ Days/Week ______ Weeks/Year

Approximate Percent Seasonal Operation:

Dec.-Feb.	Mar.-May	June-Aug.	Sept.-Nov.

Are hydrocarbon or organic solvent containing materials such as cleaning fluids, coatings, adhesives, inks, etc. used in your operation?

______ Yes ______ No If yes, please complete the appropriate forms enclosed. Make additional copies if necessary. If organic solvents are not in use or your company does not wish to participate in the survey, please sign and return.

____________________ Signature

____________________ Date

Figure 4-1 (cont'd.)

DEGREASING OPERATIONS

PAGE B

1. **Materials Processed** ______________________

2. **Type and Amount of Solvents Used:**

County Permit Number	Type of Degreasing*	Type(s) of Solvents Employed†	Amount of Solvents Added (Gal/Yr)	Amount of Solvent Removed for Reprocessing (Gal/Yr)	Normal§ Operating		
					Hr	Day	Week
EXAMPLE P99999	Vapor	Perc	2000	500	8	5	50

---

*Cold cleaning, vapor degreasing

†Stoddard, 1,1,1, trichloroethane, perchloroethylene, methyl chloride, trichloroethylene, other (specify.)

§Normal operating period - hrs/day, days/wk, and wk/yr. If the approximate percent seasonal operation differs from that on Page A, please indicate.

Figure 4-1 (cont'd.)

DRY CLEANING

PAGE C

1. Material Being Cleaned: ____________________

2. Type and Amount of Cleaning:

County Permit Number	Amount of Clothes Cleaned (Tons/Yr)	Type of Cleaning*	Type(s) of Cleaning Solvents†	Amount (Gal/Yr)	Normal§ Operating Hr	Day	Week
EXAMPLE P99999	2000	Hot	Perc	2000	8	5	50

---

* Hot unit (washing/extraction/drying in one machine) or transfer unit (use of a separate recovery tumbler)

† Perchloroethylene, Stoddard, other (specify)

§ Normal operating period - hrs/day, days/wk, and wk/yr. If the approximate percent seasonal operation differs from that on Page A, please indicate.

Figure 4-1 (cont'd.)

PROTECTIVE OR DECORATING COATINGS

PAGE D

1. Materials Coated ______________________

2. Type and Amount of Coating Used:

County Permit Number	Application Method*	Type of Coating†	Amount of Coating (Gal/Yr)	Type and % of Major Solvents		Type and Amount of Solvents Added (Gal/yr)		Method of Drying- (Air, Heat Treated)	Normal Operating§		
									Hr	Day	Week
EXAMPLE P99999	Spray	Enamel	2000	MEK	60 %	Toluene	200	Oven	8	5	50

3. Type of Cleaning Solvent: ______________________, Amount ________(Gal/Yr)

---

*Spray, dip, roller, flow, etc.

†Paint, varnish/shellac, lacquer, enamel, primer

‡Acetone, isopropyl alcohol, MEK, butyl acetate, cellusolve, toluene, other (specify)

§Normal operating period - hrs/day, days/wk, and wk/yr. If the approximate percent seasonal operational differe from that on Page A, please indicate.

Figure 4-1 (cont'd.)

FABRIC OR RUBBERIZED COATING APPLICATION PAGE E

1. Materials Coated ____________________

2. Type and Amount of Coating Used:

County Permit Number	Application Method*	Type of Coating†	Amount of Coating (Gal/Yr)	Type and % of Major Solvents		Type and Amount of Solvents Added (Gal/yr)		Method of Drying- (Air, Heat Treated)	Normal Operating§		
									Hr	Day	Week
EXAMPLE				Toluene	60%	Toluene	200	Air			
P99999	Lamination	PVC	1000	Xylene	40%				8	5	5C

3. Type of Cleaning Solvent ____________________, Amount ______________ Gal/Yr

---

apregnation, "wet" coating, hot melt coating, lamination

olyvinyl chloride, polyurethanes, etc.

oluene, naptha, mineral spirits, MEK, xylene, chlorinated hydroacrbon, other (specify)

ormal operating period - hrs/day, days/wk, wks/yr. If the approximate percent seasonal operation differs from that given on Page A, please indicate.

Figure 4-1 (cont'd.)

MISCELLANEOUS SURFACE COATING APPLICATION
(ADHESIVES, PAPER, LEATHER, FILM, GLASS, ETC.)

PAGE F

1. Materials Coated ________________

2. Type and Amount of Coating Used:

County Permit Number	Application Method[*]	Type of Coating[†]	Amount of Coating (Gal/Yr)	Type and % of Major Solvents		Type and Amount of Solvents Added (Gal/yr)		Method of Drying- (Air, Heat Treated)	Normal Operating[§] Hr	Day	Week
EXAMPLE				Toluene	60%	Toluene	200				
P99999	Spray	Adhesive	1000	MEK	40%			Air	8	5	50

3. Type of Cleaning Solvent ____________________, Amount ________ (Gal

---

[*] Spray, flow, dip, roller, brush, etc.

[†] Adhesive type, pigment coating, barrier coating, polymeric coating, inorganic coating, etc., (specify)

[§] Branched alcohol, linear alcohol, ethyl acetate, toluene, xylene, ethers, MEK, naptha, other (specify)

[#] 1975 normal operating period - hrs/day, days/wk, and wk/yr. If the approximate percent seasonal operation differs from that given on Page A, please indicate.

Figure 4-1 (cont'd.)

OVENS AND OTHER HEATED EQUIPMENT
(INCLUDE HEATED DEVICES WITH INTEGRAL OVENS ALREADY REPORTED ON OTHER FORMS)

PAGE G

1. Material Being Dried ______________________

2. Operational Data:

County Permit Number	Operation[*]	Heating Method[†]	Heater Rating (Btu/hr) and Temp (°F)	Permit Numbers of Spray Booth(s) or Coater(s) Feeding Oven	Normal Operating[§]		
					Hr	Day	Week
EXAMPLE P99999	Batch	Gas (IF)	10,000 700 °F	P99998 P99997	8	5	50

[*] Batch or continuous

[†] Electric, steam, waste heat or gas. If gas fired, specify: Indirect-Fired (IF) products of combustion not mixed with oven gases. Direct-Fired Fresh Makeup (DFFM) products of combustion mixed with oven gases. Direct-Fired Recirculation (DFR) oven gases used as combustion air supply.

[§] Normal operating period.

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Figure 4-1 (cont'd.)

PRINTING

PAGE H

1. Material Being Coated ____________________

2. Type of Printing Process and Amounts of Solvents Used:

County Permit Number	Printing Process*	Type of Ink†	Amount (Gal/Yr)	Type and % Major Solvents In Ink§		Type and Amounts of Solvents Added (Gal/Yr)§		Normal Operating#		
								Hr	Day	Week
EXAMPLE P99999	Flexigraphic	Alcohol Solvent Based	2000	Isopropanol Methanol Ethanol	70 15 15	MEK	100	6	5	50

3. Type & Amount Cleaning Solvent Used ____________ Amount ____________ Gal/Yr

*Letterpress, flexographic, lithographic, gravure, screen

†Solvent based, oil based, lacquer type, etc.

§Isopropyl alcohol, ethanol, propanol, naptha/mineral spirits, toluene, MEK, other (specify)

#Normal operating period - hrs/day, days/wk, wks/yr. If the approximate percent seasonal operation differs from that given on Page A, please indicate.

Figure 4-1 (cont'd.)

GENERAL SOLVENT USAGE

Type and amount of other solvents not identified with equipment having a county permit that were used at your facility during calendar year

Do not include any solvents that have been included elsewhere in this questionnaire.

TYPE	AMOUNT (GAL/YR)

SOLVENT RETURNED

List any solvents returned to supplier or collected for reprocessing. Again, do not include any solvents that have been so specified elsewhere in this questionnaire.

TYPE	AMOUNT (GAL/HR)

Figure 4-1 (cont'd.)

BULK SOLVENT STORAGE

Complete the following information for each storage tank greater than 250 gallons capacity.

Tank No.	Solvent Type	Capacity	Annual Thruput	Type of Fill and Control Equipment*

* Submerged fill, splash fill, return vent line, adsorber.

OPERATIONAL MODIFICATIONS

Please state the changes in type and estimated annual consumption of solvent planned for all operations for calendar years Include any information on control equipment additions or modifications.

Figure 4-1 (cont'd.)

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PAGE K

CONTROL AND STACK INFORMATION

INSTRUCTIONS:

1. Provide information on all devices that emit organic compounds through a stack, vent or other defined emission point. Identify all units under separate permits that vent through a common stack. A simple drawing may be provided to better illustrate the physical configuration.
2. Identify the primary organic compound control method used (if any) such as after burners, scrubbers, carbon adsorption, condensers, etc. Note: this device may have its own permit number. If so, identify.
3. Indicate installation date of control equipment.
4. Indicate approximate efficiency (if known).
5. Provide the following information:

   Height - distance above ground to discharge point (feet)
   Diameter - inside diameter at discharge point (feet)
   Note: if not circular, insert diameter (in feet) of equivalent circular area which can be calculated by

   $$D_e = 1.128 \ A$$

   where A is the measured or estimated cross-sectional area in sq ft and D_e is the equivalent diameter.
   Temperature - at discharge point in °F
   Velocity - at discharge point in ft/sec
   Flow rate - at discharge in actual cubic feet per minute (ACFM)

Design conditions may be used in lieu of actual test data.

County Permit Number	HC Control Eqmt	Control Eqmt Effic. (%)	Installation Date	Stack Data				
				Height (ft)	Inside Dia. (ft)	Temp (°F)	Velocity (ft/sec)	Flow Rate (ft^3/min)
EXAMPLE P99999	After-burner	95	1969	20	1.5	600	20	2100

Figure 4-1 (cont'd.)